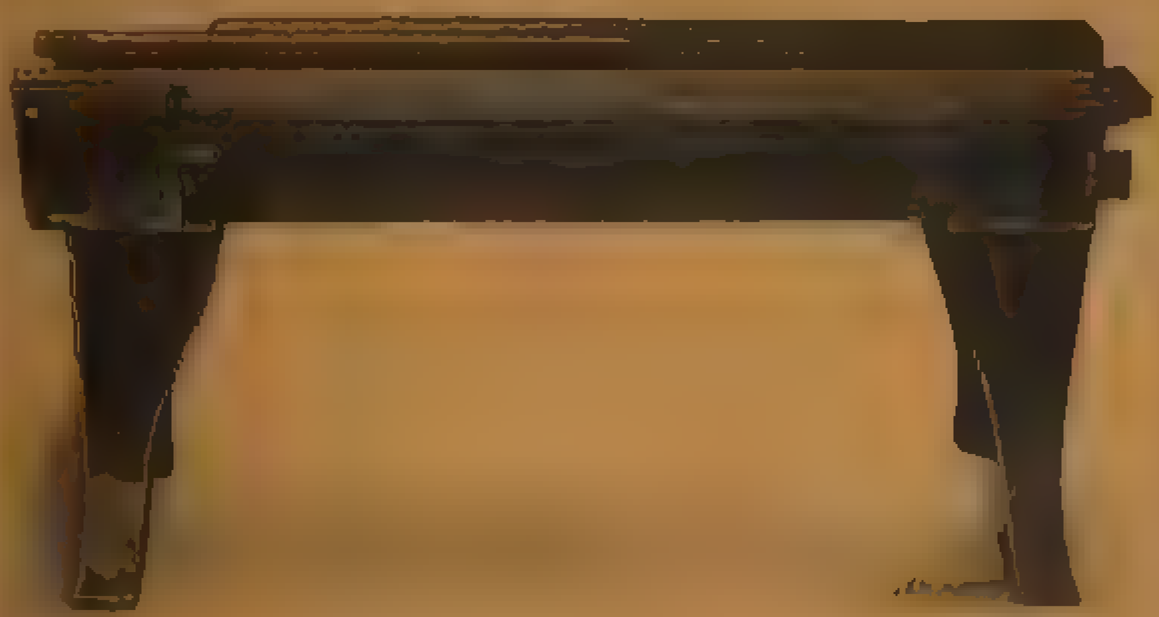
PRICE 25 CENTS

LATHE BED DESIGN

A REVIEW OF THE HISTORY, DEVELOPMENT AND PRESENT PRACTICE IN THE DESIGN OF LATHE BEDS

BY JOSEPH G. HORNER



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NUMBER 111

LATHE BED DESIGN

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CHAPTER I

THE SECTIONS OF LATHE BEDS

All the early lathe beds were made of wood. Engravings showing some of these wooden beds may be seen in old works on turning. They are to be found now only in some of the lathes used by wood-turners, and in some pattern-shops, although in the latter case, lathes with iron beds are now almost exclusively used. Fig. 1 shows a wooden lathe bed or stand. Different methods were used for attaching the bearers or shears to the uprights. At a very early date the wear of the top surfaces of the wooden bearers was prevented by screwing thin flat iron plates onto them. Strips of wrought iron were also fitted, having curved edges chipped and filed to shape, as shown in Fig. 2. There was not a great deal of durability in these shears, but the chief objection to this construction was that when the timber warped, as it was bound to do in the course of time, it pulled the iron strips with it, and threw the headstock, tailstock, and rest out of alignment.

The first all-iron beds were of triangular section, the form probably originating with Henry Maudslay. The bed was built of two bars of triangular section, secured in brackets bolted onto the legs. There was a very good reason for the adoption of this form of bed in preference to any other. There were no planing machines at that period—in the latter part of the eighteenth century—so that it was an important consideration to be able to reduce the chipping and filing to a minimum on a single bar. Besides, if the two upper faces were true, it made no difference whether the bottom one was true or not, because there was clearance between it and the tailstock and rest.

Lathe beds with a single shear of triangular section have often been built, although they are seldom seen now, except in the lathes used by watch- and clock-makers. These beds are sufficiently rigid for light duty, and chips do not lodge on them. The triangular-section lathe bed also possesses the virtue of insuring self-alignment of the tailstock and rest, which bear on the upper edges only. The essentials of the triangular bar section have been revived and perpetuated in the Pittler bed—referred to later—but in a modified and stronger, stiffer, and steadier form. The Pittler bed consists of a bar of trapezoidal section. The bar is hollow, and the lead-screw, passing through the hollow section, is thus protected. In some watchmakers' lathes, the essential features of the triangular bed are retained, but the lower side is of convex form. Some lathe beds are of cylindrical cross-section, either solid or hollow. All these types are simply variations of the single bar type, and are illustrated later in this treatise. Mention may also be made of square and rectangular beds, the latter being employed in a few of the peculiar French lathes used for screw threading.

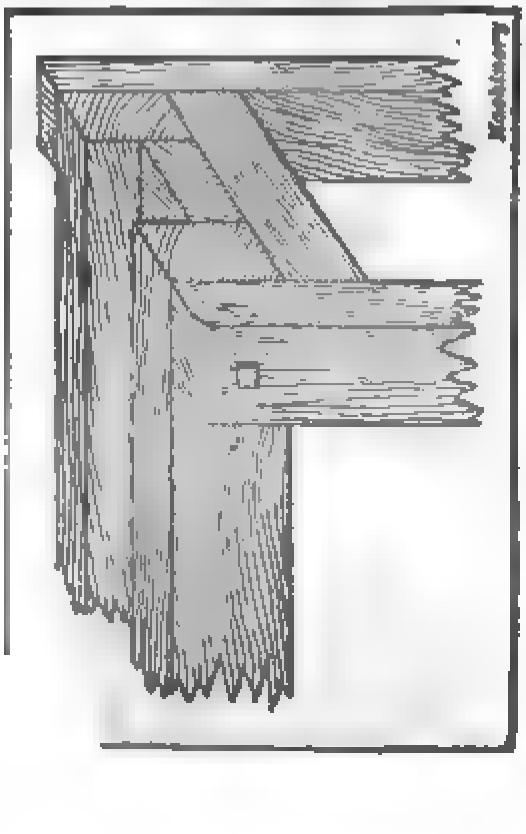


Fig. 1. A Common Type of Early Wooden Lathe Bed

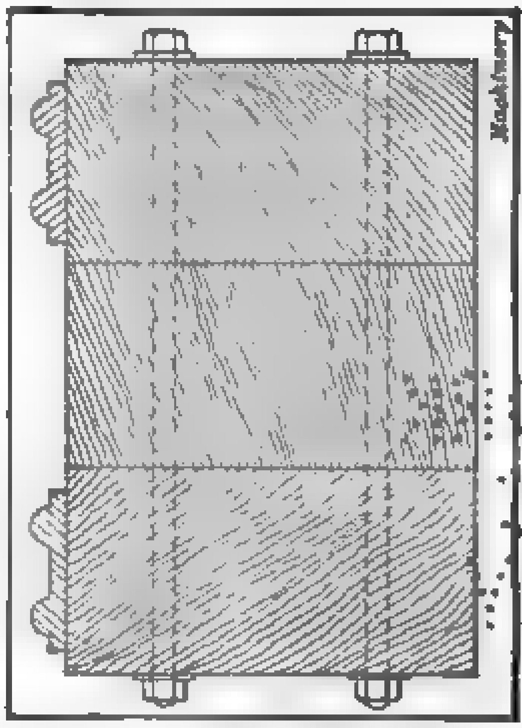


Fig. 2. Built-up Wooden Lathe Bed provided with Iron Ways

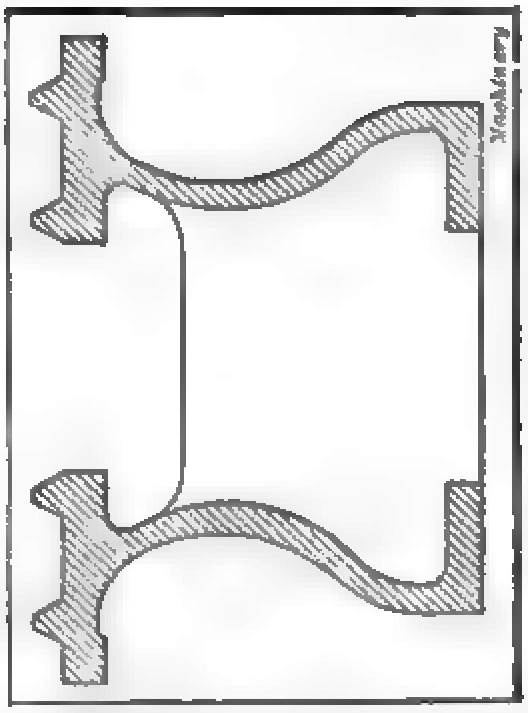


Fig. 3. Early Type of American Lathe Bed with Double Vee Guides

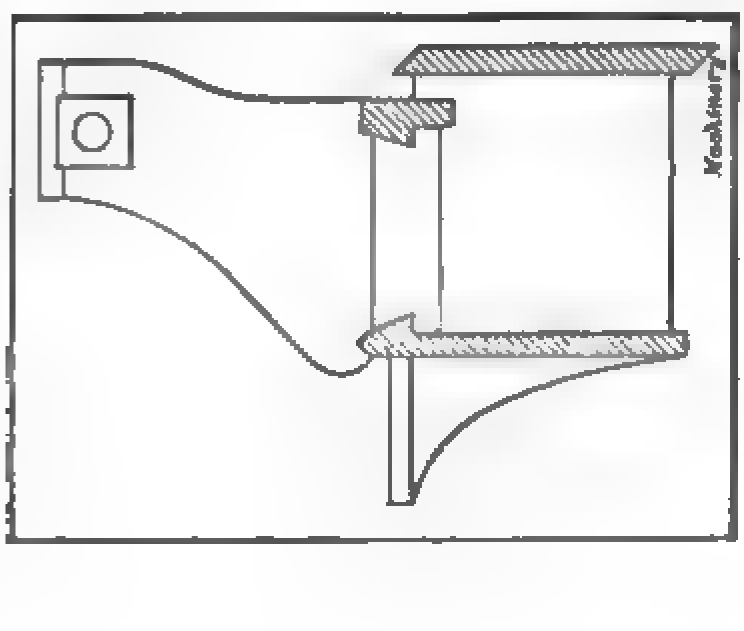


Fig. 4. Early Front Slide Lathe Bed

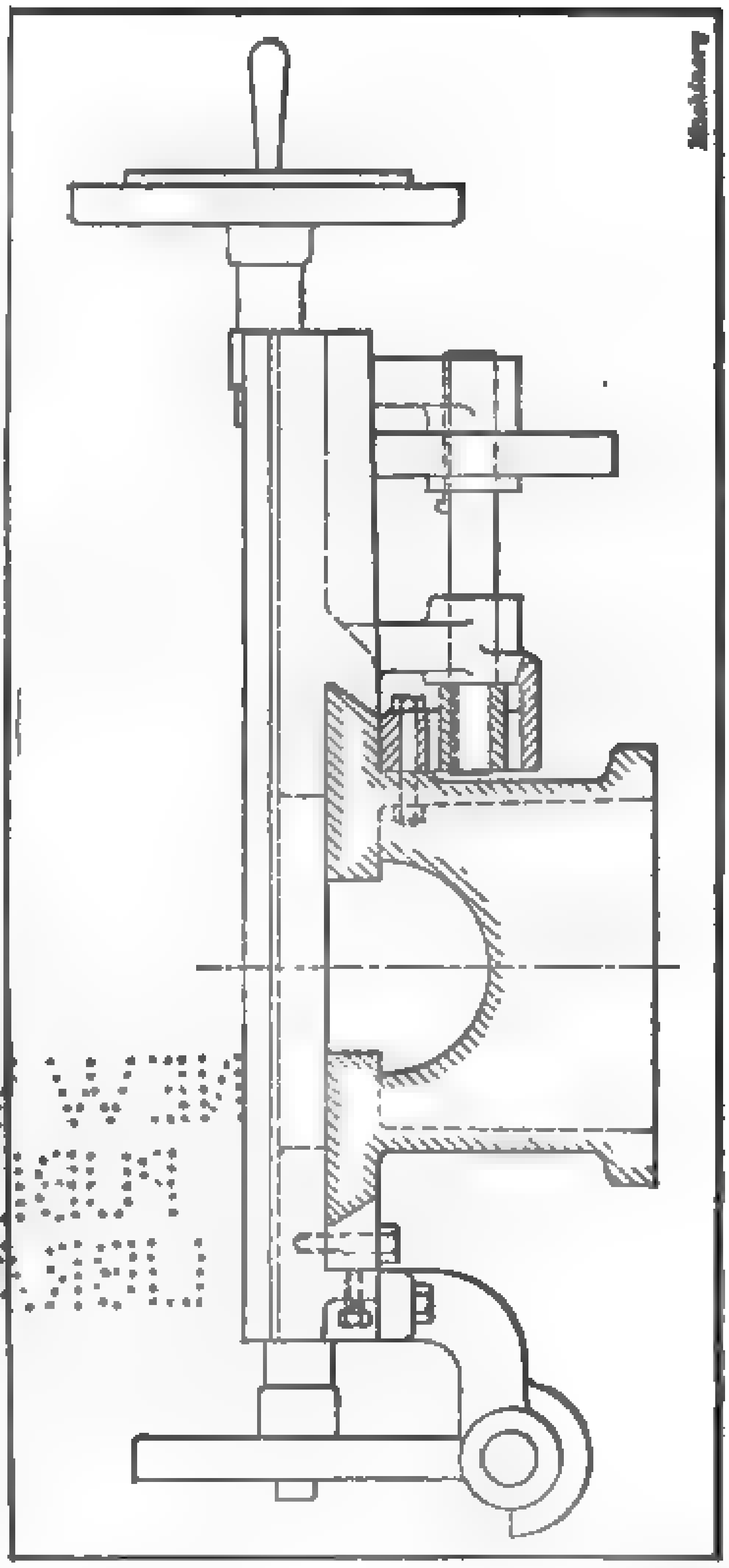


Fig. 5. An Ordinary English Type of Lathe Bed

Early Development of Lathe Beds

Since a single triangular bed was not stiff enough to resist the torsional stresses of heavy cuts, which produce vibration and cause the bed to spring, an early development was that of using two deep parallel bars or beam sections, cast separately and bolted together. In the next stage the two bars were cast in one piece with connecting ribs. It was still, however, necessary to reduce the labor of chipping and filing to the least amount consistent with the practical requirements of the time; hence the form shown in Fig. 6, in which the top vees of the triangular bars were still retained, represented standard practice, with or without the internal stiffening ribs which were cast to increase the rigidity in the lateral direction. Then modifications of the design in Fig. 6 were introduced as shown in Fig. 7, where one vee is dispensed with, but the other retained for guidance. In Fig.

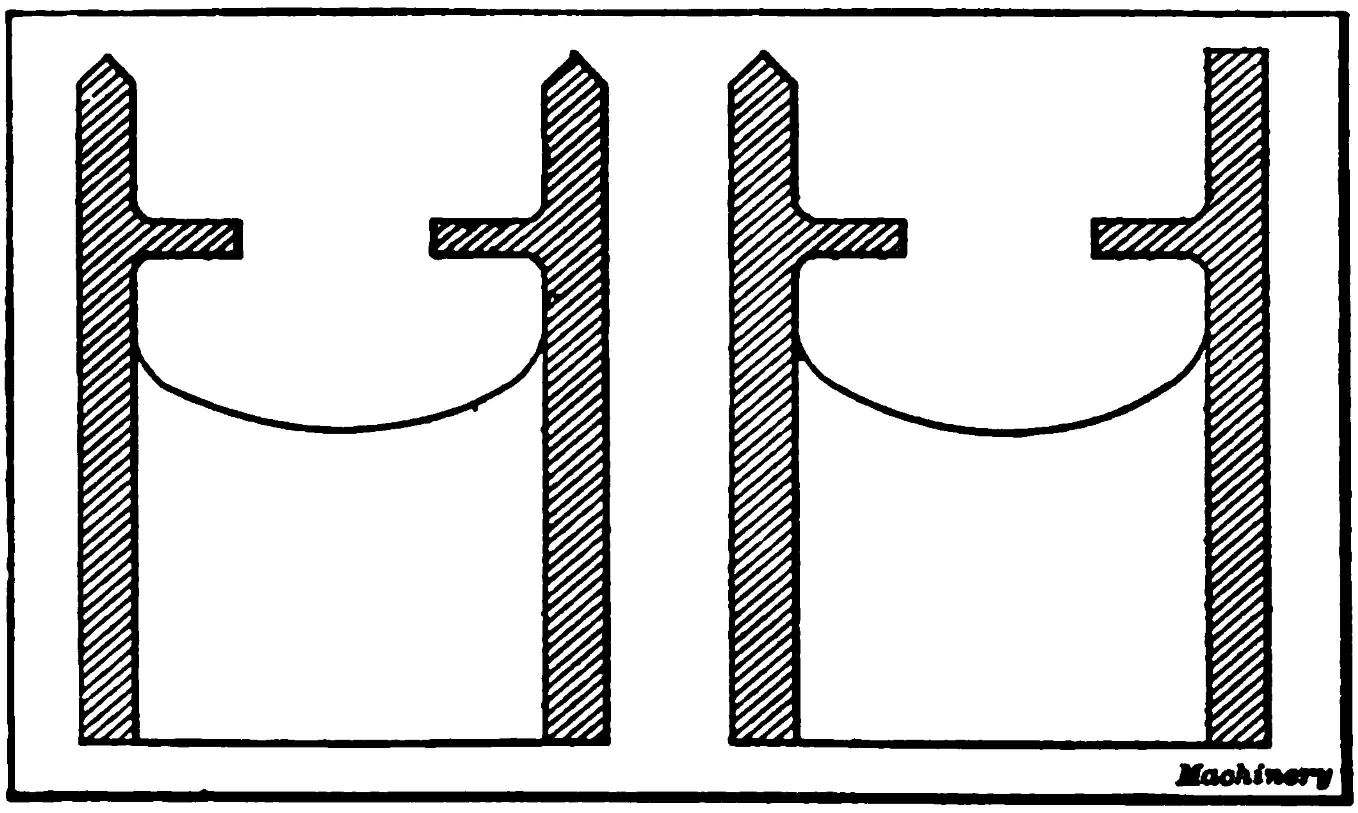


Fig. 6. Early Type of Lathe Bed with Double Vee

Fig. 7. An Early Lathe Bed with a Vee and a Flat Way

8, the width of the flat bearing surface is increased. This type of bed also made it easier than with two vees to fit the parts to a nicety. This construction is, for the same reason, employed instead of two vees in many lathes and grinding machines to-day. At last both bearing faces were made flat as shown in Fig. 9, and the longitudinal means for guidance offered by the vees was, therefore, abandoned. The lateral play was then prevented by making tenons on the heads fit between the edges of projecting internal ribs, as shown in Fig. 9. All finished surfaces were still kept narrow, however, until, after the invention of the planer, they developed into the present forms.

As the slide-rest developed, the battle of the vees and flats became intensified. The older upstanding vees are still retained—with modifications—as the only guiding elements in standard American practice. At a comparatively recent date slight modifications have been made in some forms, in which a flat is combined with the vees; but the principal difference which exists even now is that of using either two or four distinct vee-ways. In the latter design, Fig. 3, the two inner

vees guide the sliding tailstock, and the two outer ones, the carriage or saddle of the slide-rest. The inner vees are frequently sunk below the level of the outer ones to increase the swing of the lathe, and to enable a greater thickness of metal to be put into the carriage. Both vees are truncated or flattened more or less on the top. The type hav-

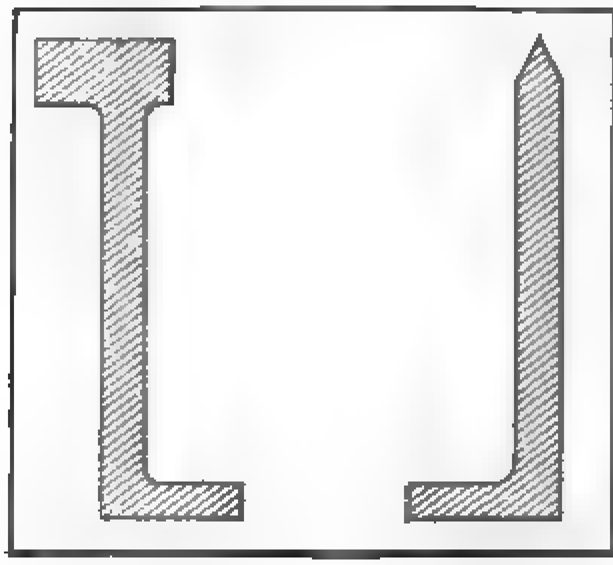


Fig. 8. Another Type of Lathe Bed with One Vee and One Broad Flat Shear

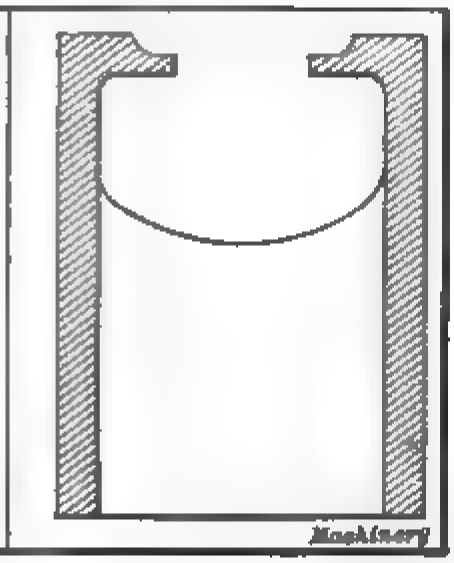


Fig. 9. Lathe Bed with Two Flat Ways

ing two vees only, serving both for the carriage and the tailstock, is now chiefly used for the smaller classes of lathes. In England, the vee-beds have been long since abandoned, except in a very few cases where an Anglo-American design is aimed at.

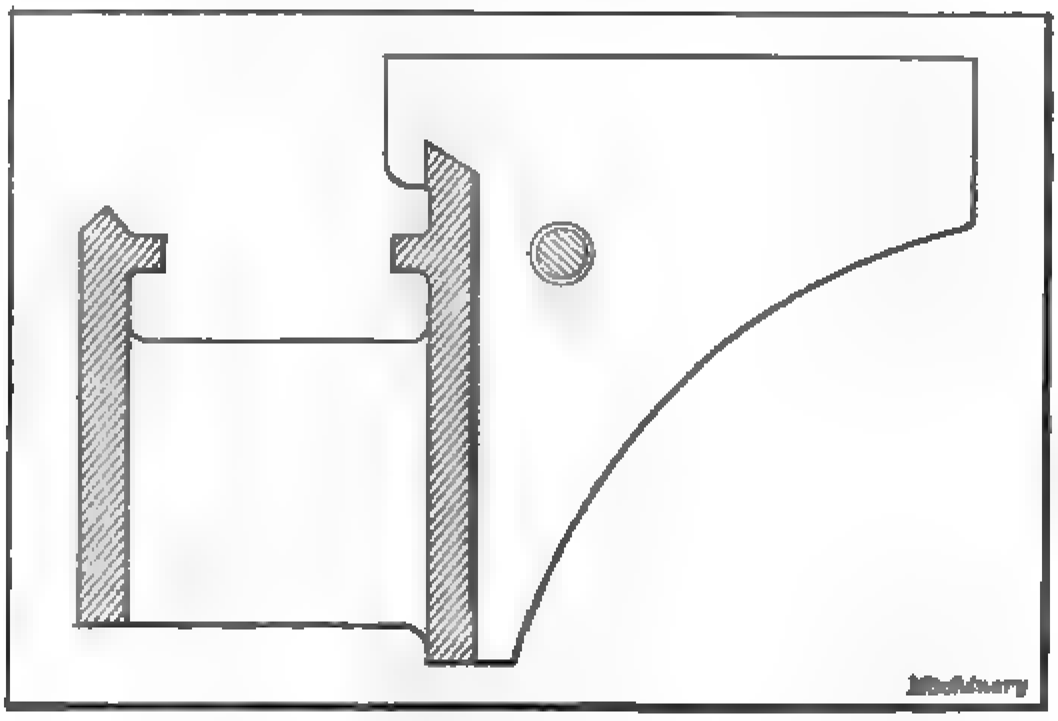


Fig. 10. Early Type of the Richard Roberts Lathe Bed with Front Slide

Some of the early lathes with vees anticipated the modern forms of front-slide lathes. Figs. 4 and 10 illustrate beds of this type, as constructed by Richard Roberts, of Manchester, from about 1817 to 1820. They were probably the first of that type, and they do not differ essentially from modern lathes of a similar kind. In these illustrations

two variations are shown. In one, dependence is placed on the guidance of one vee only, and the lower edge of the front slide bears against a plain face. In the other, a bottom vee is included, with a setting-up strip. Note in Fig. 4 that the centers of the heads are brought forward in front of the bed center. The remainder of the design is in harmony with the practice of that period.

Fig. 11 illustrates the section of the bed of a large lathe which also

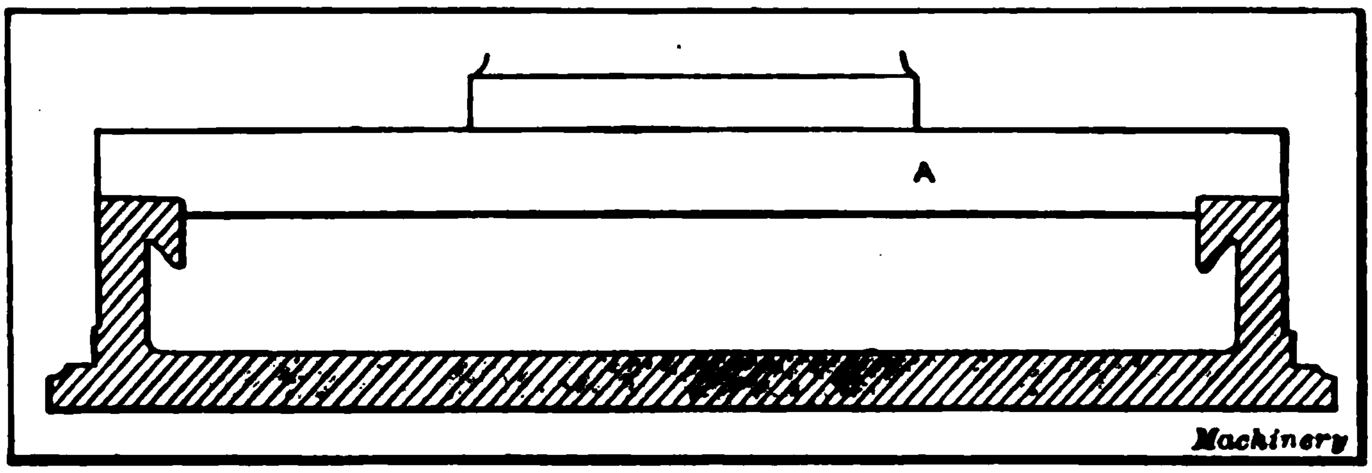


Fig. 11. Early Type of Bed for Heavy Lathes

was designed to perform the function of a boring mill; it was built by a Dundee firm before 1847. In this case the bed is very shallow, and its ways flat, with internal inverted vees. The plate *A* represents both the base of the tailstock and the carriage of the slide-rest. Hook-bolts embracing the vees and passing up through the plate, were used for

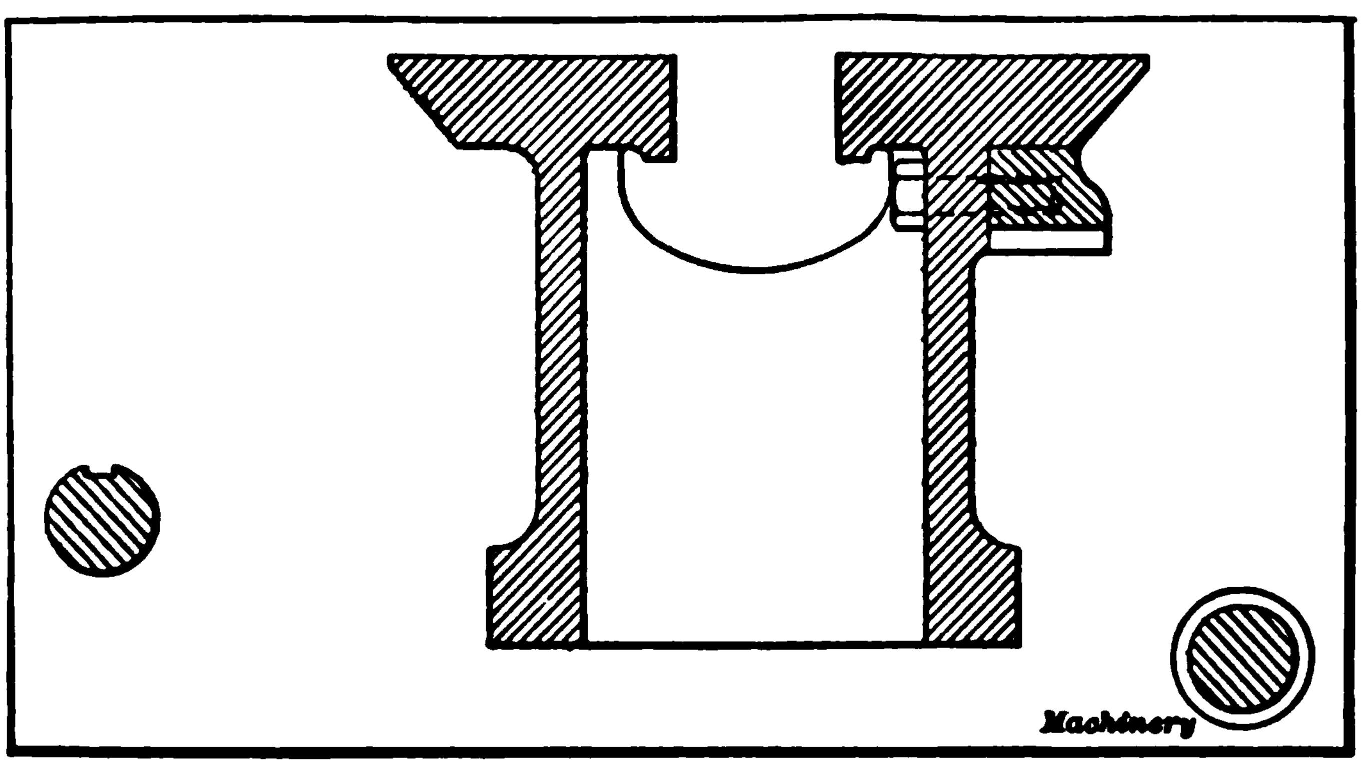


Fig. 12. Type of English Lathe Bed, Standard for a Long Period; Lead-screw and Feed-rod in Unsatisfactory Positions

clamping. In this machine, as in some others of that period, no power feed was available to the carriage, but only a hand traverse of the tool-holder. The carriage was adjusted by hand through a pinion and rack. In this lathe, the movements of the carriages of fifty years earlier were thus retained.

In the usual type of English lathe bed, Fig. 12, the vees are abandoned for ways having broader surfaces, and their place as guides is taken by the edges of the ways. The inner edges take care of the alignment of the headstock and tailstock, and the outer ones take care of the slide-rest or carriage. The outer guides may either both be in

the form of vees, as in Figs. 5 and 12, or one may be square and one vee-shaped, as in Fig. 13. In some cases both edges may be square. These types have long been standardized, but there are many variations. It is from this starting point that we propose to consider the forms of lathe beds as they are designed to-day.

Flat vs. V-Shaped Lathe Shears

The transition from the upstanding vees to the flat ways has been a gradual one. The adoption of one flat with one vee, which dates a century back, has gone through various phases of development, besides those shown in previous illustrations. In America, an old type of bed by the Brown & Sharpe Mfg. Co. (who do not now make ordinary turn-

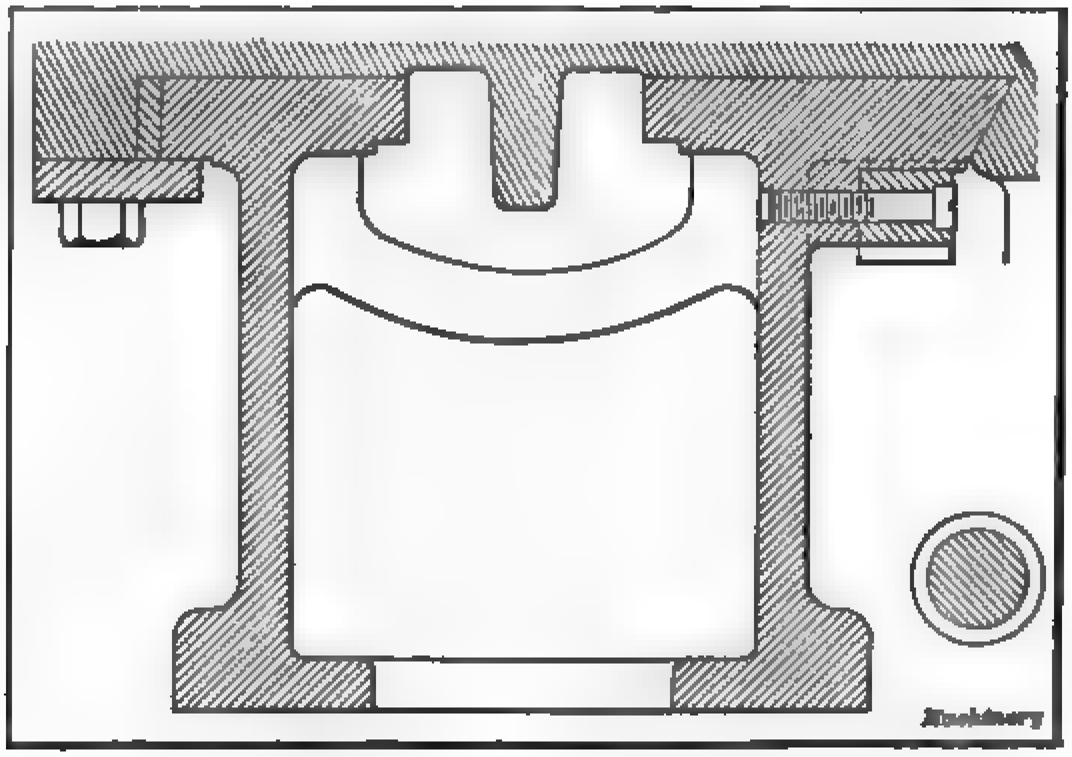


Fig. 13. Another English Lathe Bed of Standard Design

ing or "engine" lathes) was substituted for the beds with four vees. In this case the vee was employed for guidance, in conjunction with a suspended weight. The carriage was also gibbed on the square edge, which was situated at the back of the lathe. The Pratt & Whitney Co.'s tool-room lathe has a bed of the vee and flat type, as shown in Fig. 14. This design is also interesting because of the use made of a coiled spring in place of the suspended weight, which, through its inertia, is liable to cause vibration.

The battle between the vees and flats has given occasion to much fruitless controversy, since both types are retained tenaciously. There is much to be said in favor of the guiding qualities of an upstanding vee, and much also for the greater durability of a broad flat surface, and of the solidity of the carriage employed in conjunction with the latter. That these differences were recognized at an early period is evidenced by the frequent combination of a vee with a flat, and also by the use of two sets of vees, the outer set being reserved for the slide-rest or carriage. This not only divides the wear due to the move-

ments of the tailstock and the carriage between two sets of vees, but also affords a broader base for the carriage, with corresponding gain in its stability. The self-aligning property of the vees is too obvious to require demonstration. In the flat beds self-alignment is absent. If the tenons of the tailstock wear, a loose fit results. In many lathes, however, provision is incorporated for clamping the tongue of the tailstock against the edge of one way only, thus not attempting to make a fit against the other. As a rule, the headstocks are then not fitted at

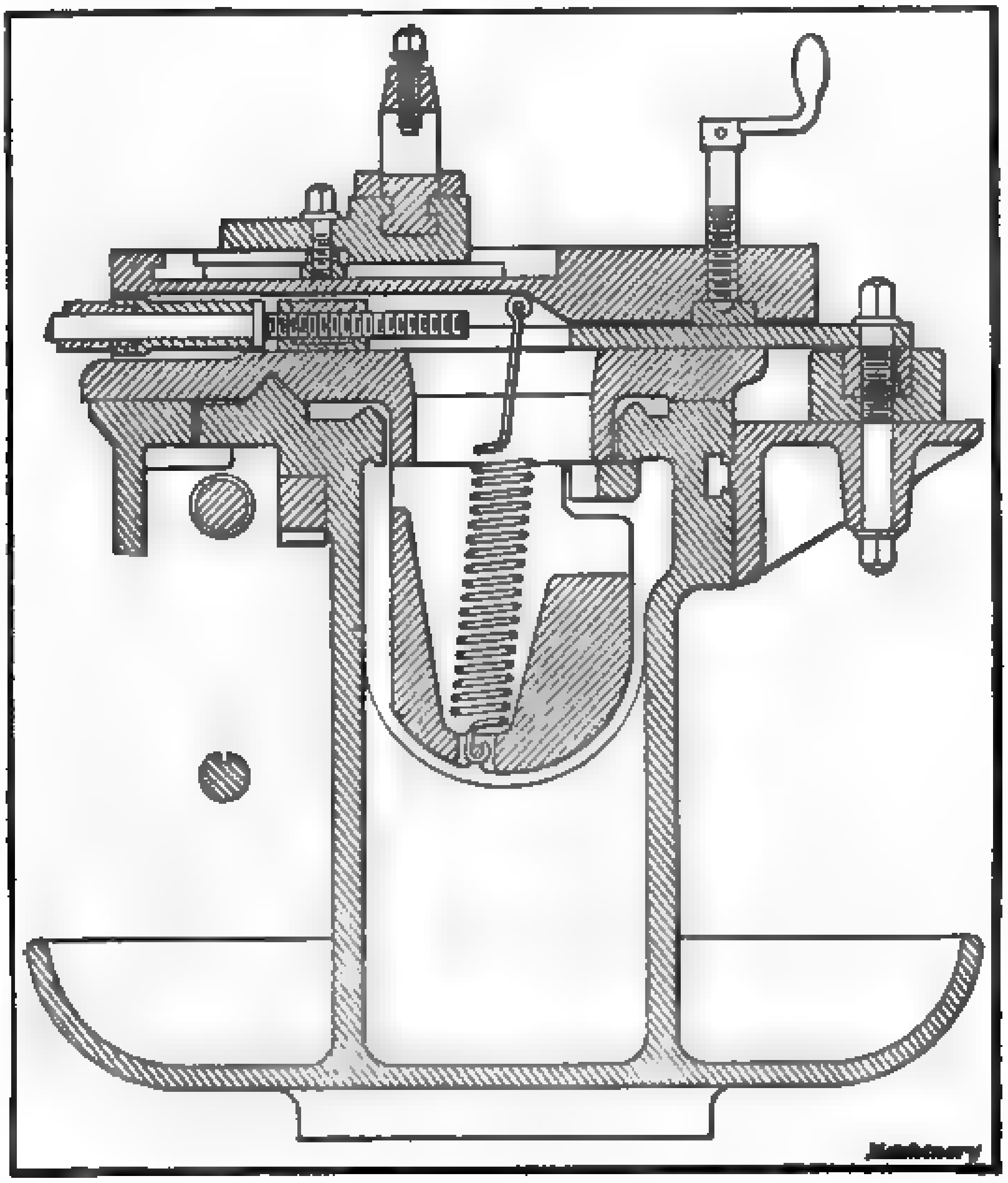


Fig. 14. Bed of Tool-room Lathe built by the Pratt & Whitney Co., Hartford, Conn.

all, but are adjusted by means of screws passing through the tenons.

Though the wear on the vee-ways is uniform, they lack the advantage which the flat ways with vee-edges possess, namely, that of preventing the saddle of the slide-rest from being lifted during cutting. Hence all the early beds were commonly united only at the ends, leaving the entire length clear for a holding-down device, frequently consisting of a center-weight suspended from the carriage, and traveling with it, as shown in Fig. 15. When increased duty was demanded,

and the beds were tied together with cross-ribs, the suspended weight could not be used. Then clamping or gib-plates were introduced underneath the edges of the bed, as in those English designs which have square edges. Sometimes the gib or gibs are fitted underneath the internal edges. An example of this, taken from an Italian lathe, is shown in Fig. 16, where one gib strip is located on the outer lip of the back shear, and another on the inner lip of the front shear, this arrangement being adopted because the construction of the carriage does not provide room for a strip at the front edge. Gibs bearing against both the inner and outer lips are also employed.

The points in favor of vee-shears may be summarized as follows: The wear is uniform, and loose fits cannot develop as in flat ways with

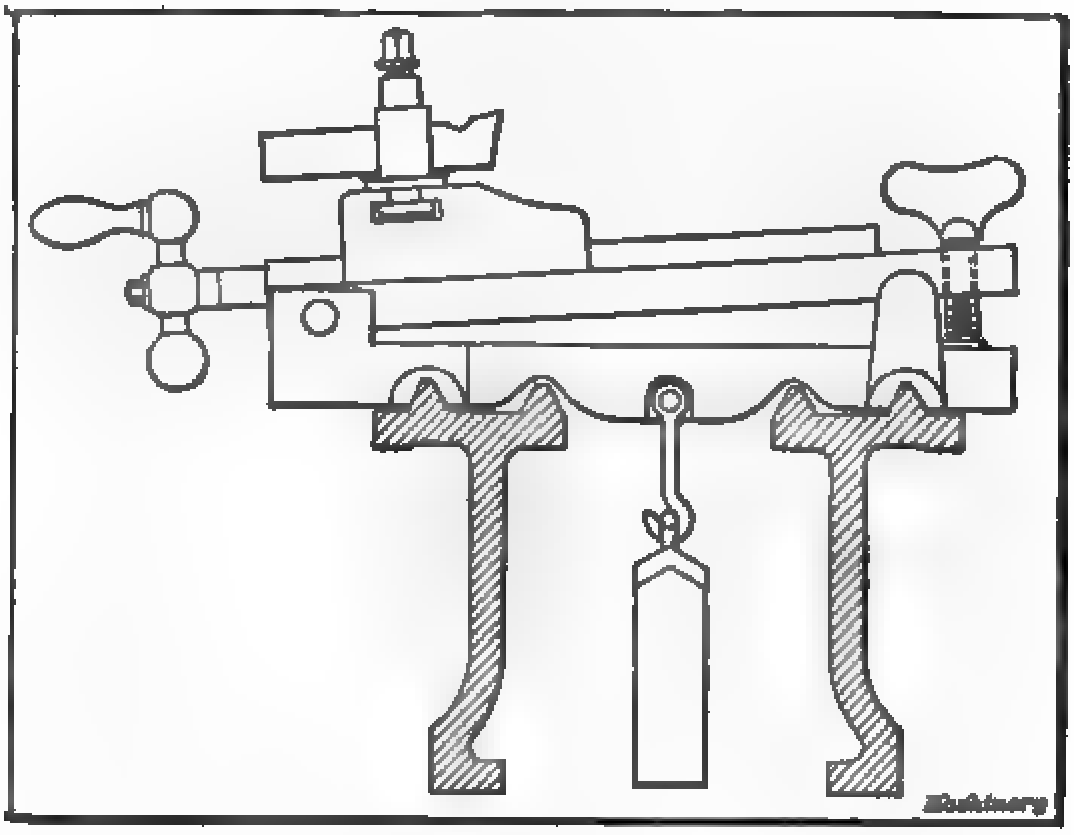


Fig. 15. Lathe Bed with Weighted Carriage

square edges; the chips fall off freely; the rapidity of the wear can be largely minimized by increasing the length of the carriage; and the clamping of the heads on the vees helps to tie the sides of the bed together and stiffen them. The risk of damage to the edges of the vees, which might be mentioned as an objection to vee-shears, can be lessened by rounding them. The arguments in favor of flat ways and against vees are briefly: Wear is so long delayed that little account need be taken of it; its effects can be counteracted by fitting the tenons of the tailstock to the edge of one shear, and as regards the saddle by the setting-up of the gibs; the elevation of the vees permits of less swing than do the flat ways.

Location of Lead-screw and Feed-rod

Inseparable from the design of the bed sections are the problems of the location of the lead-screw and feed-rod. It is an interesting fact

that the old eighteenth-century lathe of Maudslay's has the lead-screw enclosed within the shears of the bed, thus anticipating the Whitworth design of nearly half a century later. The Whitworth bed, with the location of the lead-screw, is shown in Fig. 17. In this the divided clasp-nut is retained, operated by cam plate and levers through pulling or pushing a rod which passes to the front of the saddle. The support-

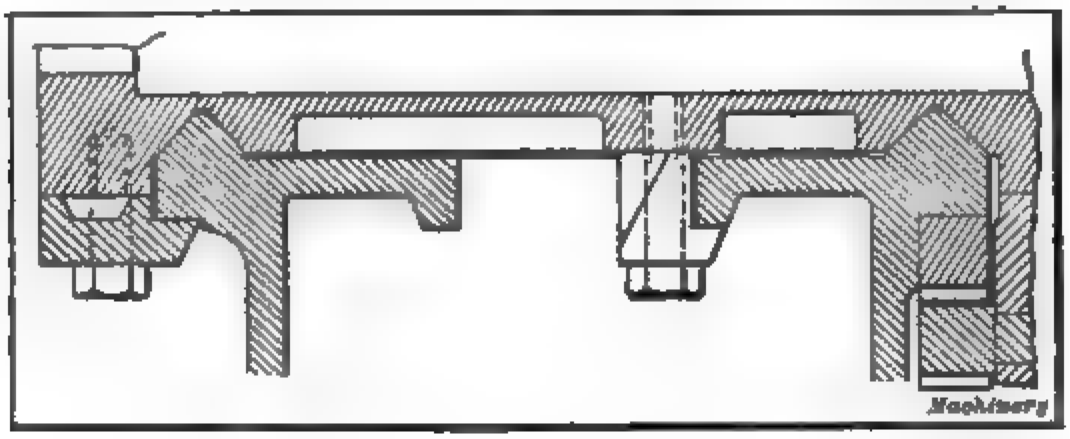


Fig. 16. Example of Gibbed Vee Bed

ing bearings for part of the circumference of the lead-screw should be noted. The position of the rack is not always as shown; frequently it is placed at the front of the bed. Fig. 18 shows a special Whitworth bed having the lead-screw placed exactly in the center, supported around nearly half its circumference by bearings located at intervals.

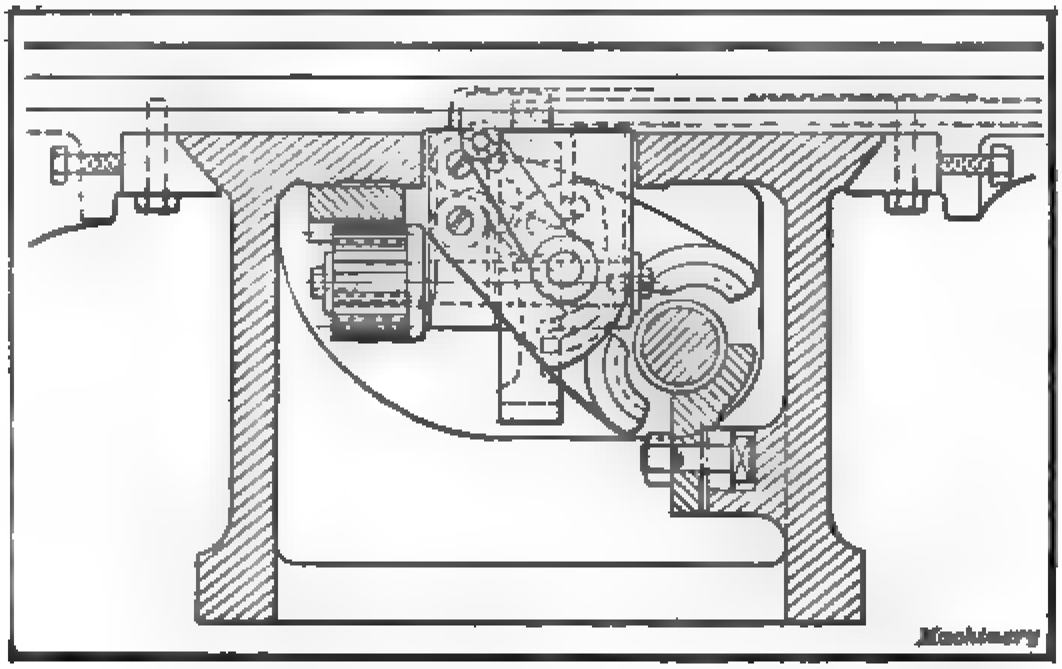


Fig. 17. The Whitworth Bed used in Lathes built by W. G. Armstrong, Whitworth & Co., Manchester, England

Several firms manufacture lathes with lead-screws protected in various ways. In standard English practice the lead-screw has long been placed outside at the front, and the feed-rod or "back-shaft" outside at the back. (See Fig. 12.) As a result of the influence of American practice many lathes are now built with lead-screw and feed-rod both in front and close together, and both with the rack traverse operated by gears enclosed in an apron. This is in harmony with the

idea of obtaining the motion required for screw cutting and feed from a gear box on the bed in front of the headstock; it also permits a more compact arrangement of the carriage. It may be stated as a general rule that the best English makers now place the feed-rod in front in preference to placing it at the back, and there seems to be no doubt but that in a short time the old "back-shaft" will disappear.

Development of the Sellers Lathe Bed

The section of a bed used in lathes built by Messrs. William Sellers & Co., Inc., as shown in Fig. 19, illustrates the transitional form which under different modifications appears in many lathe beds of the present day. The vee-sections at the sides in the illustration represent the earlier, and the central portion, the later type. The earlier design is

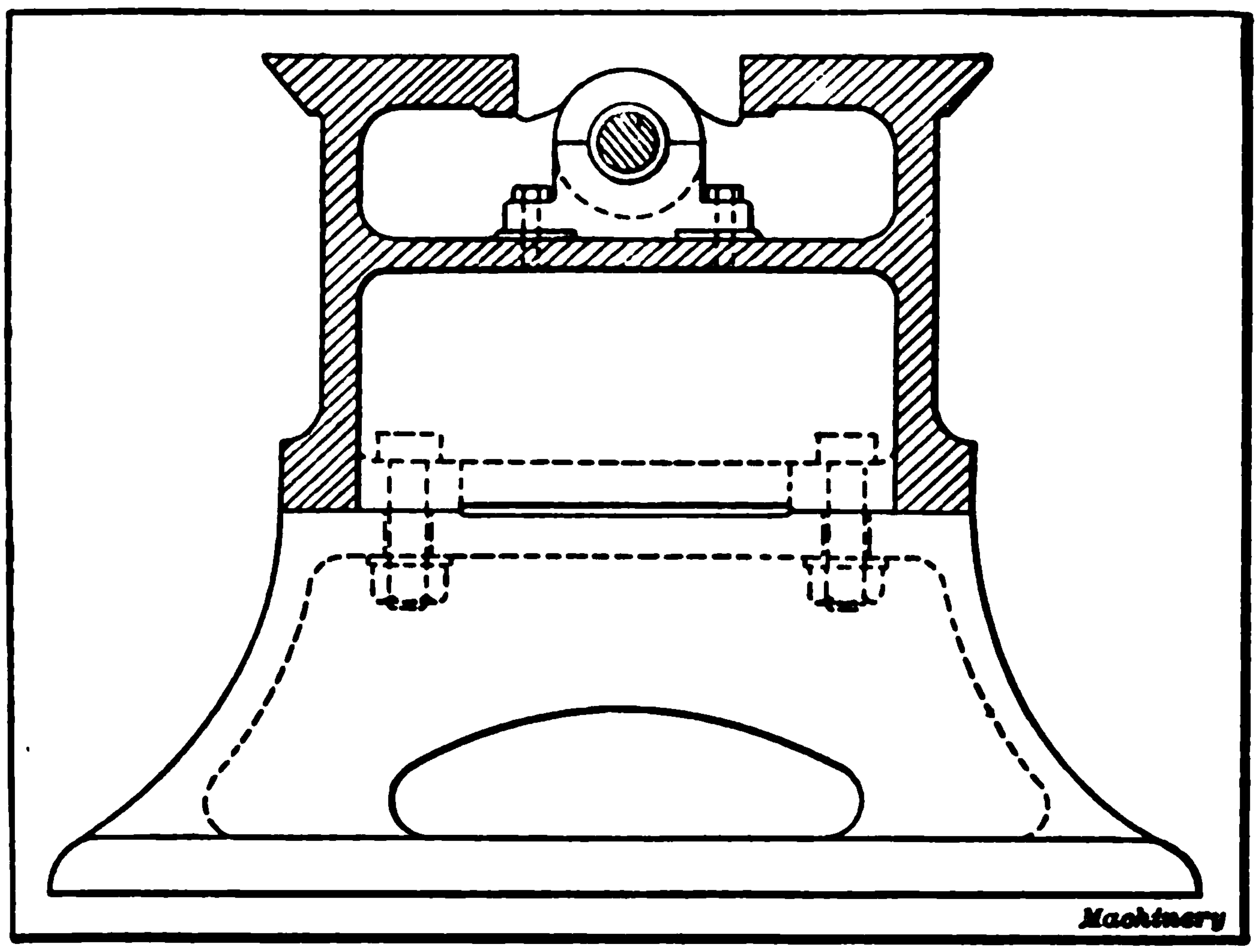


Fig. 18. A Whitworth Lathe Bed with a Central Lead-screw and Web

similar to the standard English bed, in so far as the fitting of the sliding parts to flat ways and vee-edges at front and back is concerned; but the lead-screw is protected under the front shear in a recess provided specially for it. An inverted vee underneath the back shear is used to clamp the tenon of the tailstock against the vertical edge of the back shear, instead of trying to make its tenon fit between both shears permanently, which is not practicable. Messrs. Sellers & Co. adopted this method in order to retain the same advantage of alignment (notwithstanding wear of the tenon or tongue of the tailstock) as is secured by the use of vee-ways, thereby taking advantage of the durability of the flat ways without suffering from the disadvantage due to the wear of the tenons.

The experience with the beds having vee-edges at front and back, as shown at the sides in Fig. 19 demonstrated that almost the only wear which occurred took place on the top faces, and not on the

beveled edges; hence the abandonment of the vees in favor of square edges which maintain the traverse of the carriage parallel with the axis of the live and tailstock spindles, while the inverted vee maintains the tailstock spindle in alignment with the live spindle. The

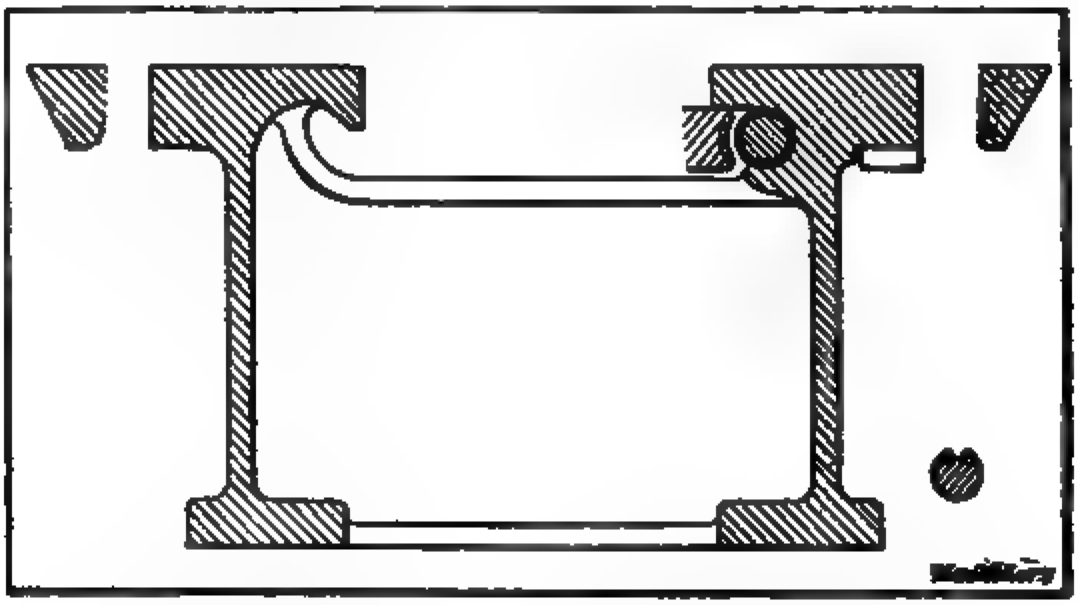


Fig. 19. A Type of Bed used in a Lathe built by Wm. Sellers & Co., Inc., Philadelphia, Pa.

later type, therefore, provides for the permanent retention of the accuracy imparted to the lathe when new, and also provides for the protection of the lead-screw. The advantages of this design have been

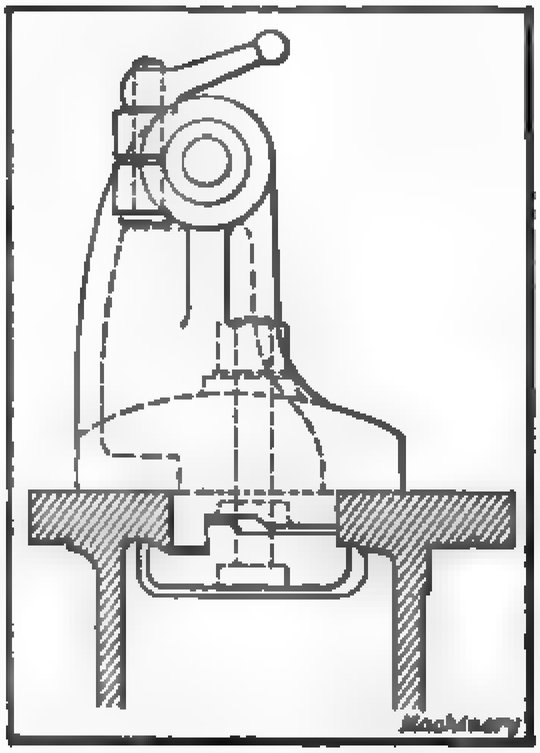


Fig. 20. Lathe with Inverted Vee for Clamping, built by G. Birch & Co., Manchester, England

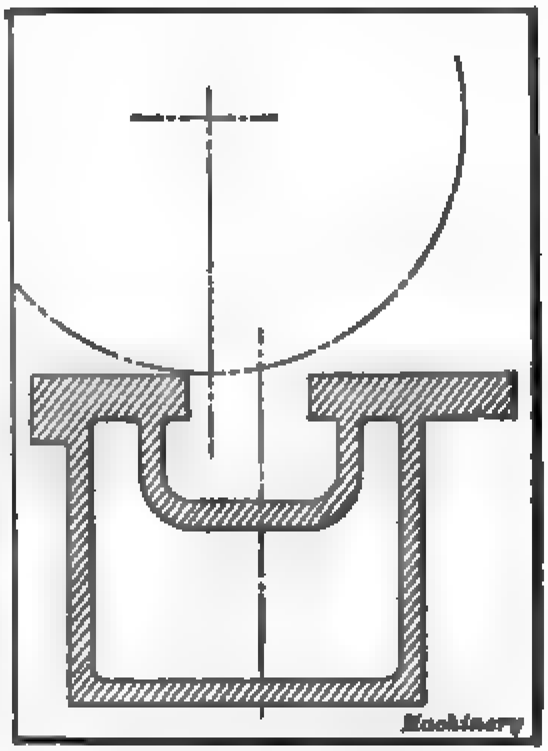


Fig. 21. Closed Box Lathe Bed of a Type Manufactured by Thomas Ryder & Son, Bolton, England

recognized, and it has been imitated in numerous later lathes.

The protection afforded to the lead-screw is so important a matter that many devices for this purpose have been adopted since the time when Whitworth placed it within, instead of outside, the shears. The

Sellers' design embodies a decided improvement, for in it the lead-screw is supported along its entire length by the recess which is provided for it, and, therefore, it cannot be deflected. But the half-nut is single, and only extends around a rather small arc of the circle. These Sellers' beds also were among the first American designs which embodied the use of cross-ribs.

Two examples of the employment of the inverted vee are seen in Figs. 20 and 22, the first showing the arrangement of the clamping plate in relation to the tailstock tongue, and the second a somewhat similar construction on a German chucking lathe. The base of the turret in this latter case is always pulled over toward the inner edge

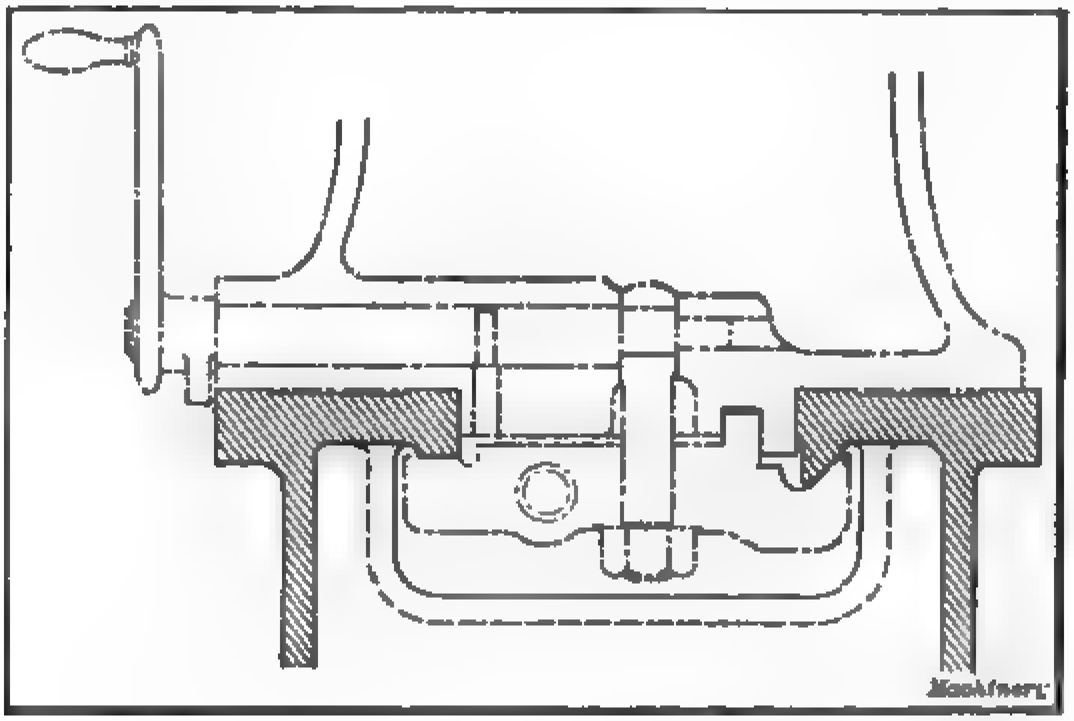


Fig. 22. Inverted Vee Lathe Bed for Clamping Turret Base, made by De Fries & Co., Dusseldorf, Germany

by the action of the clamping plate, which is pulled upward by means of an eccentric bolt and lever.

Strength of Lathe Beds

Another development is that of the stiffening and strengthening of lathe beds. All the old types were mere skeletons, although some of them were stiffened laterally as shown, with ribs placed internally or externally. Gradually, the thickness of the metal was increased, and the ways widened; fillets were cast along the bottom edges in addition to the cross-ribs. Many of the American beds were of a highly molded section, as shown in Fig. 3, with the object of imparting stiffness chiefly in the lateral direction, and so help to compensate for the absence of cross-ribs.

Lathe beds must always be made much stronger than they would have to be in order to merely prevent fracture. The stresses to be resisted are in the first place flexure; but it is fully as important that the design be stiff enough and heavy enough to resist the tendency to torsion and to vibration—to chattering. The massing of the metal may solve the problem, but it must be done judiciously. Flexure may be

met by increasing the depth, because the strength increases as the square of the depth. Torsion is more difficult to prevent, while resistance to vibration demands a mass of metal obtained only by considerably increasing the dimensions which are required to prevent flexure and torsion. Experiments have been undertaken at various times from which certain broad deductions have been made; but lathe beds are, notwithstanding, mainly evolved from previous practical experience. Although the general movement has been going on for a century, this evolution has been especially noteworthy since the advent of high-speed steel.

The flexure of a lathe bed is more than allowed for by the proportions given to it for general strength. A very light bed might possibly be bent by the placing of a very heavy piece of work between the

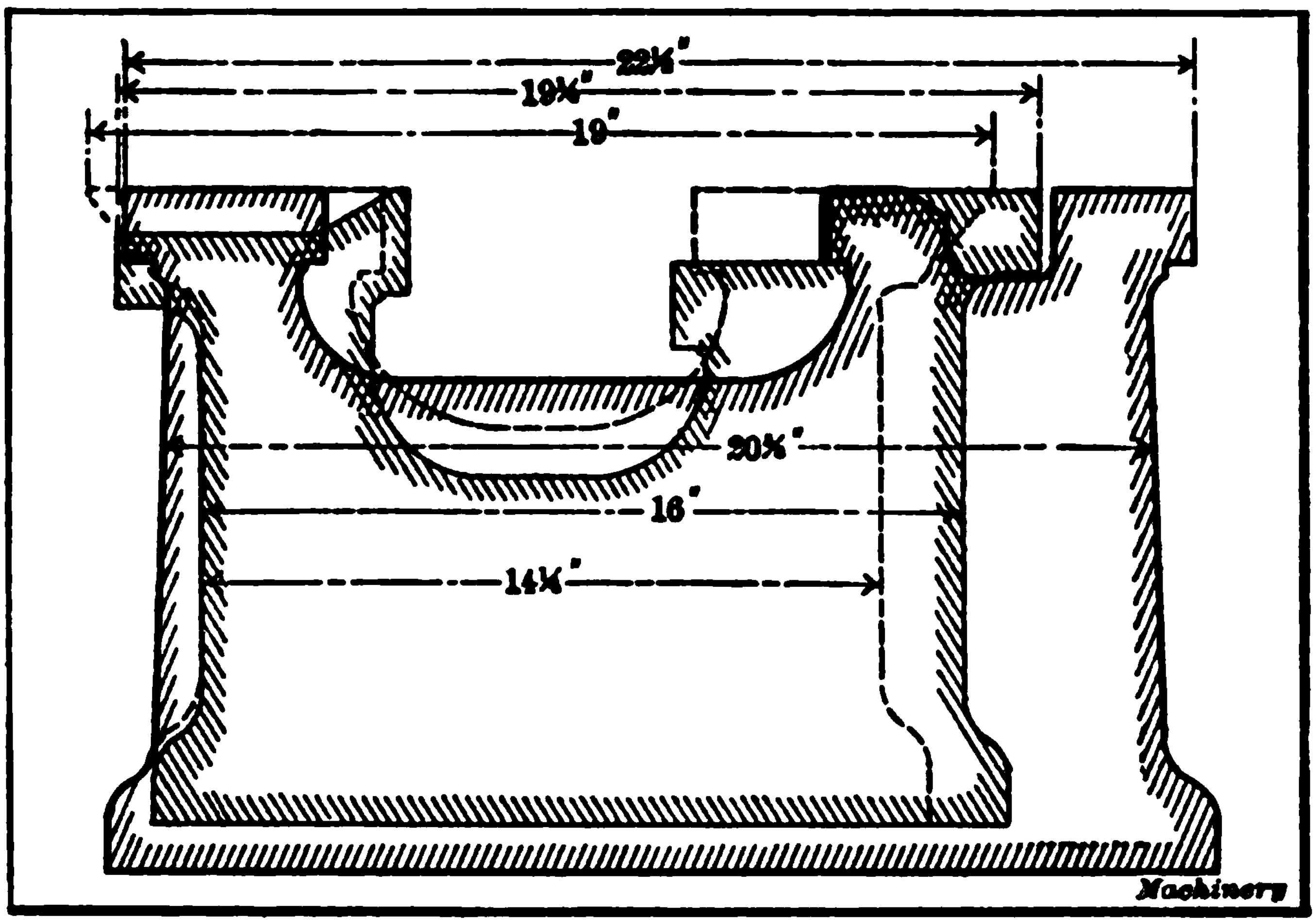


Fig. 23. The Evolution of the Lang Bed

centers, or by the stress of heavy cutting near the center of the bed. In some American beds the standards or legs have been set a certain distance inward from the ends in order to shorten the length of the unsupported portion. Sometimes the beds are cambered or fish-bellied; long beds have legs in addition to those at the ends; or in heavy lathes, the bed is continuous and rests on foundations located at intervals. An unsupported length which will not bend, provided the bed is of box section, is given by Mr. Richards as one which is not more than twelve times its depth.

An interesting example of the gradual increase in bed dimensions for one size of lathe is shown in Fig. 23. This engraving illustrates the evolution of the lathe bed of Messrs. John Lang & Sons, of Johnstone, Scotland. The ordinary English type is seen in dotted outline; this type was employed by the firm previous to 1900. The thin full lines show the first narrow guide type of bed of 1900, and the thick full lines the present type.

Torsion can be best avoided, as far as the shape of the bed is concerned, by making it of a box section. Comparatively few lathe beds are, however, constructed in that manner, the general design being that of two shears connected by cross-bars or ribs, thus leaving the top and bottom edges unconnected. That this is a poor design is admitted, but it is one which is more easily molded than a box shape. Long ago Prof. Sweet had some castings made for a test, as indicated in Fig. 24. These castings represent, respectively, the open-frame and the box

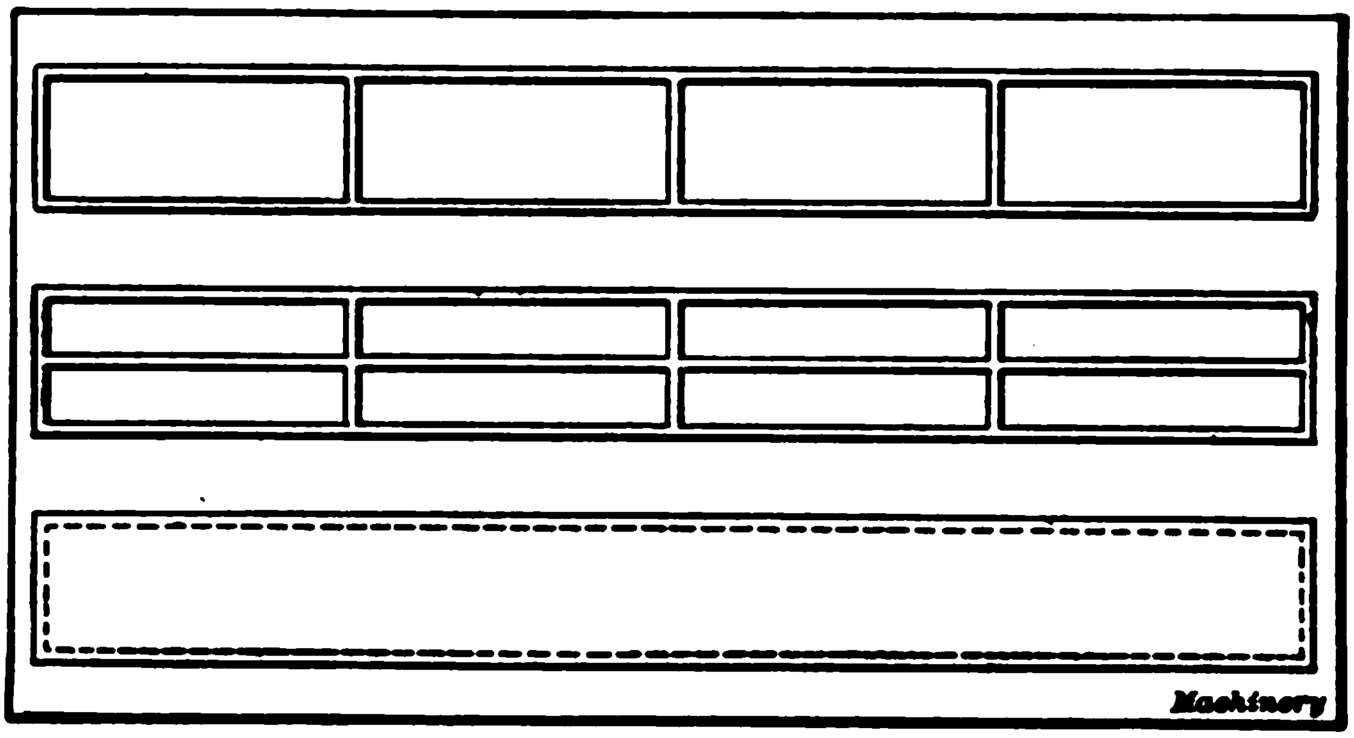


Fig. 24. Experimental Beds investigated by Prof. Sweet

type of beds, with the same amount of metal in each. The box casting proved much stiffer laterally, and thirteen times more rigid against torsion.

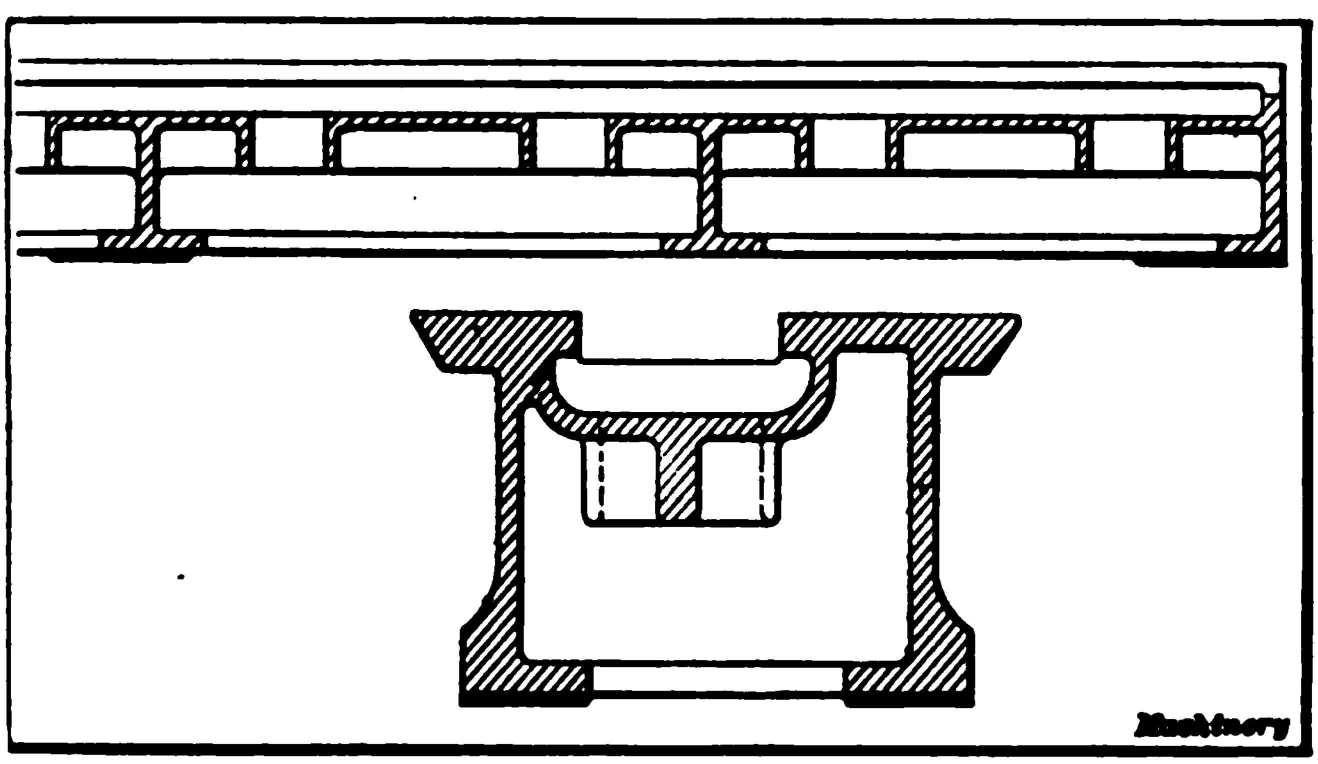


Fig. 25. The Richards Box Bed

Several firms now construct beds which are wholly or partially boxed. It is, of course, necessary to leave some provision in the form of openings for the escape of chips and oil. Messrs. George Richards & Co., Ltd., of Manchester, England, though they have now given up the manufacture of ordinary lathes, were in the field when this departure was made. Their first lathe beds were made as shown in Fig. 25. The beds were practically encased along the top, and well tied to the

cross-ribs along the bottom with broad flanges. Holes cast in the top casing permitted the chips to fall through. The holes were surrounded by a rib to prevent loss of strength due to the cutting of the holes. Otherwise in its general design, the bed is of ordinary English type, with flat ways, vee-edges, and a gap.

In Fig. 21 is shown a section of the beds of the lathes manufactured by Messrs. Thos. Ryder & Son, of Bolton, England. These beds are of solid box section. In this design the practice of bringing the lathe centers considerably behind the center of the bed is adopted, in order to afford additional support to the cutting tool when turning large diameters. The depth of the rear guide strip of the bed is also deepened to increase its durability.

Dr. Nicolson has stated that if the same amount of metal put into

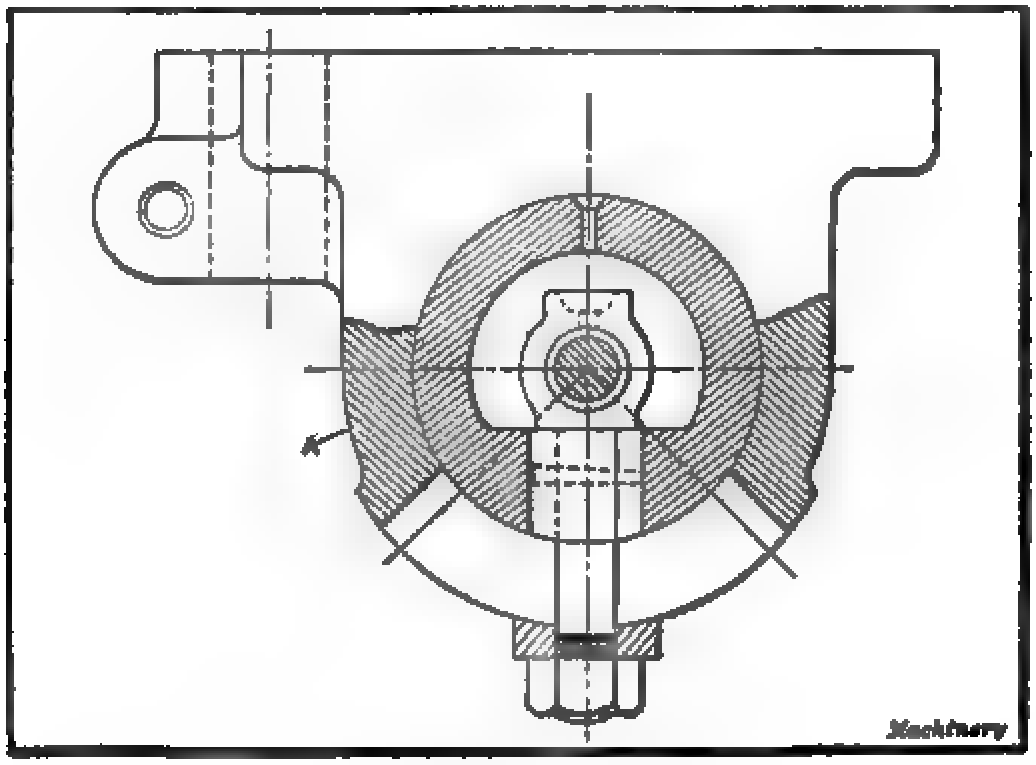


Fig. 20. Section of the Circular Bed for Lathes made by Drummond Bros., Guildford, England

the ordinary beds were put into the box-shaped or the circular form, these types would be from six to ten times as strong to resist twisting. This is not so high an estimate as that given many years ago by Prof. Sweet, but it is amply high enough to justify that departure from the old practice which several lathe makers now have adopted. The solid box form is practicable, and easily manufactured; but the circular form is not, except in light lathes, such as those used by watch- and clock-makers, amateurs, and scientific workers. For such purposes, several examples of this type are built. The circular bed must have a longitudinal guide or guides for the headstock and slide-rest or carri- and it is here that the difficulty arises in massive designs. In the heavy designs, the circular bed may be dismissed as nearly imp- ble, or at least undesirable, in face of the fact that boxed be- tangular section can be and are constructed better and m- and of equal strength.

The circular bed is cheaply made for small lathes of, say, from 6- to 10-inch swing. It is used for these, not so much because it happens to be the stiffest form, but because of the advantage which it offers for swivelling the rest to different angles, thus making it a kind of universal tool for all kinds of cutting. This design is adopted in the recent lathes of that type built by Messrs. Drummond Brothers, Ltd., of Guildford, England. The bed, of cast iron, 3 inches in diameter, is of hollow form, ground on the outside to a limit of 0.0001 inch, and on it the heads and saddle fit. As seen in Fig. 26, there is a slot in the under side of the bed which receives a tongue or bush secured to the bolt that passes up to transmit the motion from the lead-screw. By tightening

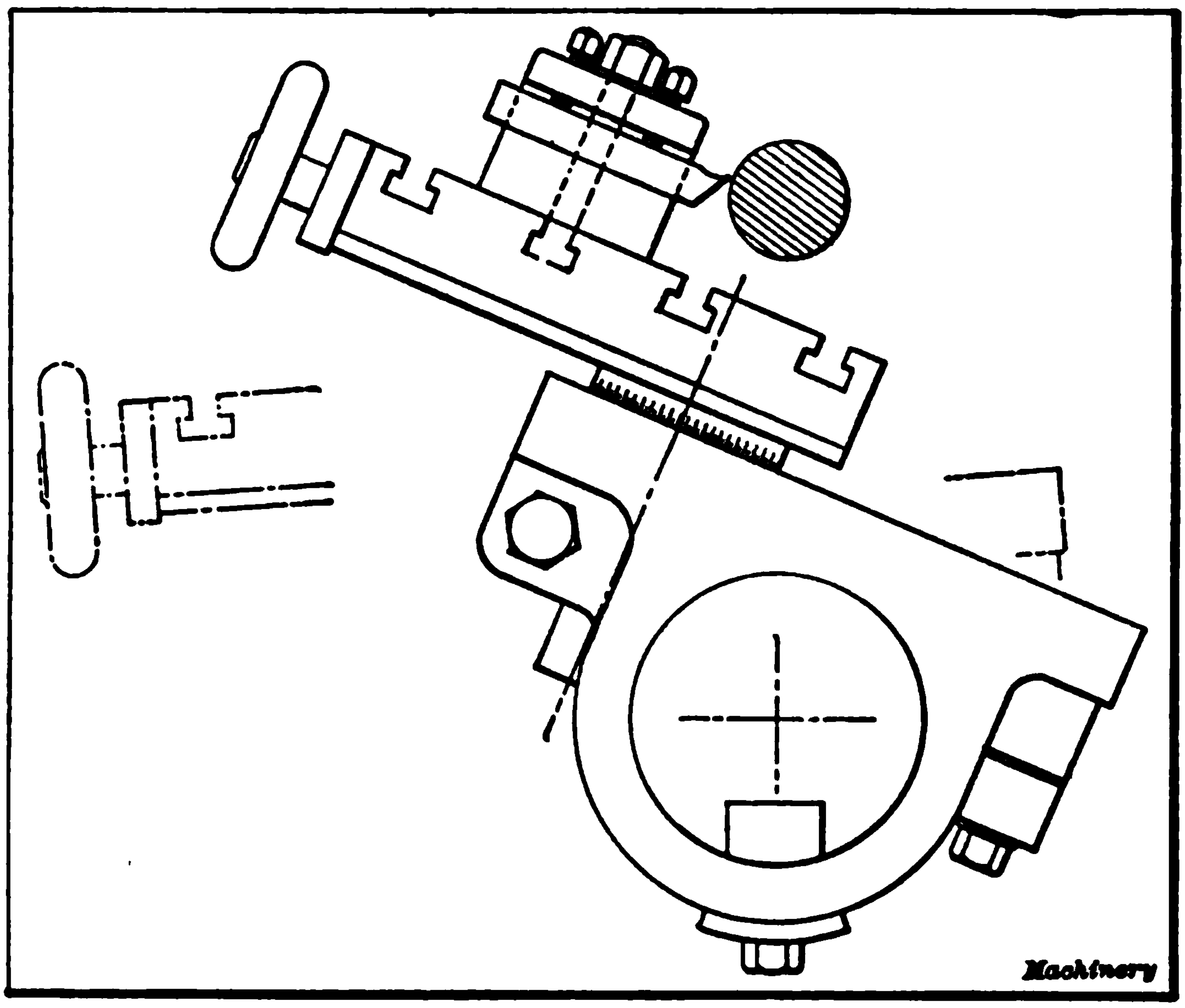


Fig. 27. The Drummond Lathe Bed and Saddle

the nut on this bolt the swivelling portion *A* is locked. The range of swivel is indicated by the radiating center lines. Fig. 27 shows the complete tool-rest, with the upper part held in the split socket of the saddle, thus permitting of a horizontal swivel movement which enables the tool, or the top of the rest, to be moved in a universal manner.

This lathe, in its swivel action, resembles the Pittler lathe, although the latter is designed in a different way. In the Pittler lathe, the longitudinal guidance is provided for by a section of trapezoidal shape, within which the lead-screw passes. The form of this bed is plainly indicated in Fig. 28. The swivel motion is provided for by making the outside of the sliding carriage circular, and fitting the saddle of the slide-rest to it. In this way the sliding movement is combined with a circular movement through a complete circle. The stem of the tool-rest can be swiveled in the socket in the split saddle. The

greatest swing to which lathes of this model are built is 14 inches. Pittler lathes of greater swing are built with approximately rectangular beds, having a vee and a flat guide.

The advantage of the circular form is also recognized in cases where it cannot be adopted absolutely. Some of the bench lathes have beds of D-section; one made by the Pratt & Whitney Co., of Hartford, Conn., is shown in Fig. 28. The headstock, tailstock and slide-rest are clamped to the flat top-face and are guided by the two sloping edges, thus preserving the alignment. The bed being small, is cast in one piece with its two feet.

The "Narrow Guide" Lathe Bed

We now come to a recent development in lathe bed practice, which has already, in the short course of some five or six years, effected a

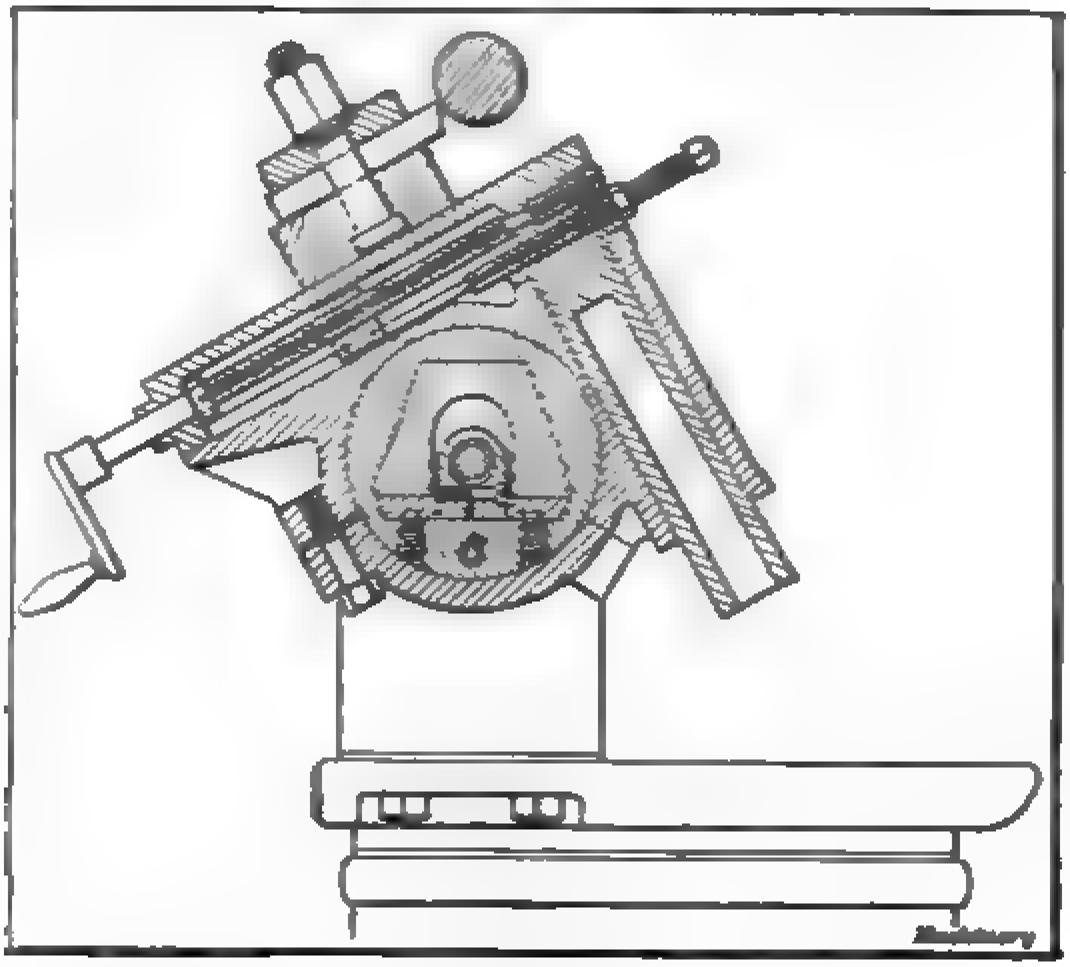


Fig. 29. The Pittler Trapezoidal Bed used by the Leipziger Werkzeugmaschinenfabrik, Leipzig-Wahren, Germany

remarkable revolution in lathe construction—the application of the principle of the narrow guide. This principle, although so lately taken up in earnest, is not by any means new. To determine the period of its first application would seem impossible, but illustrations showing the idea applied to lathe carriages appeared some twenty-five years ago. The three illustrations Figs. 30, 31 and 32, are taken from Joshua Rose's "Modern Machine Shop Practice," and show how the principle was applied many years ago. All three of these illustrations are re sented in recent practice, and it is noteworthy how the constr has been brought into prominence chiefly by the development speed lathes. Messrs. John Lang & Sons, when they re-des

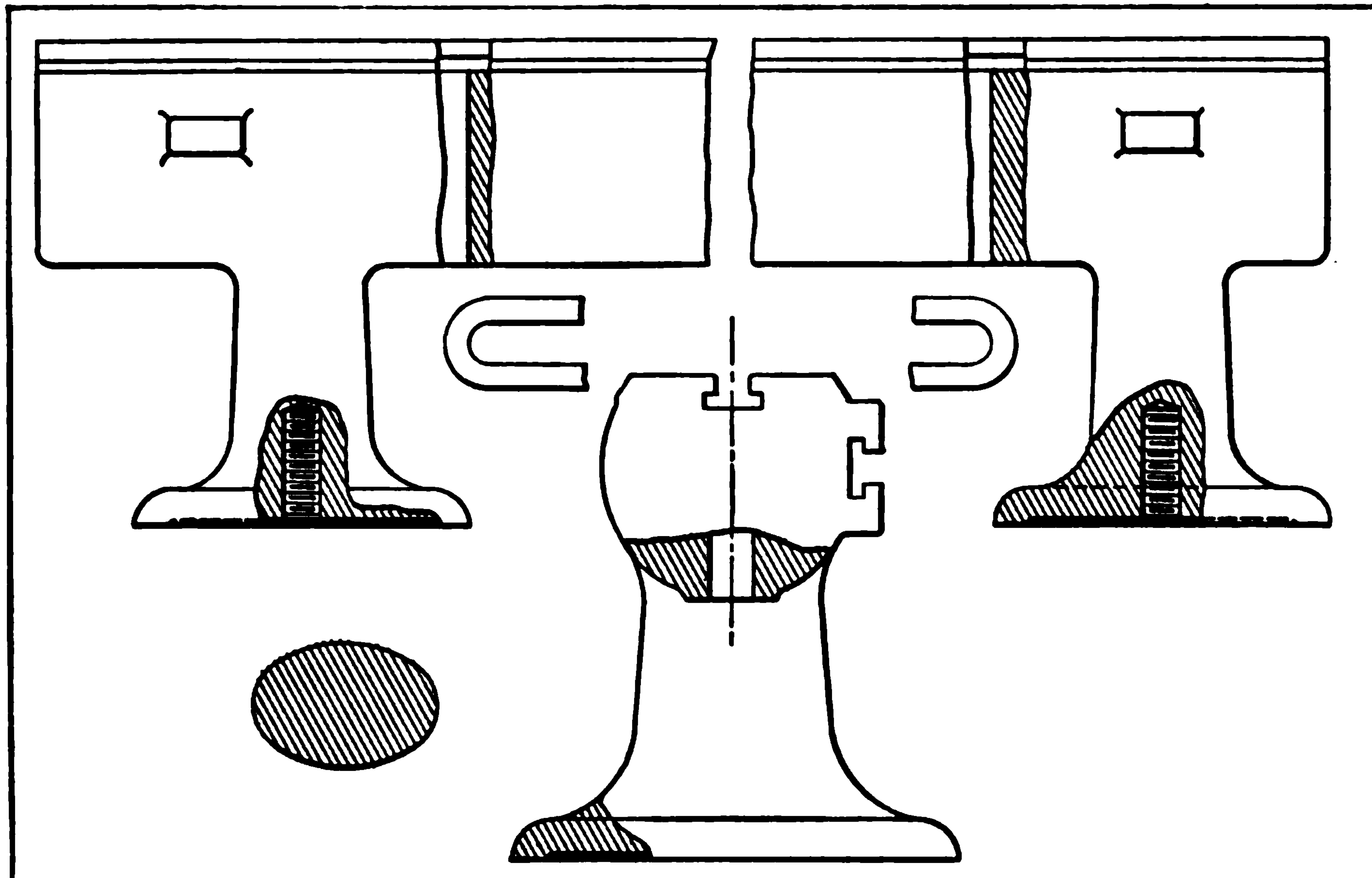
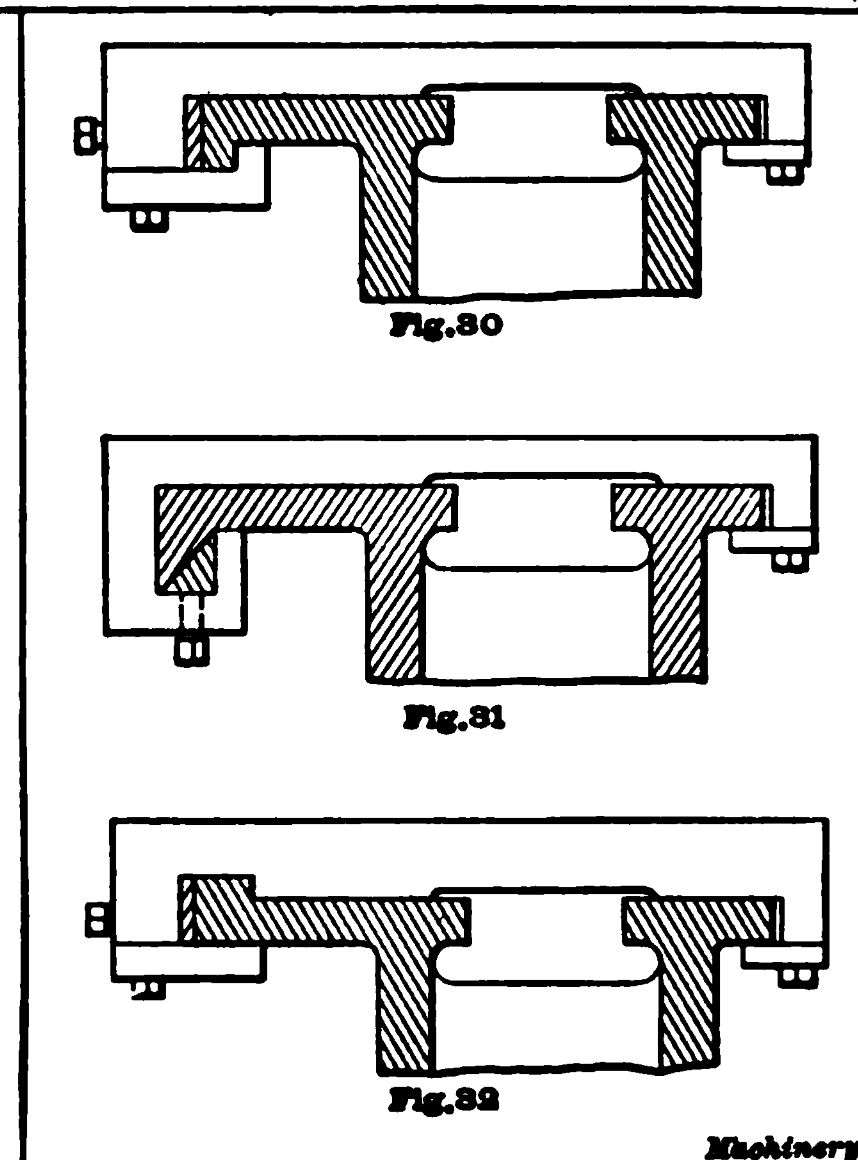


Fig. 29. Bed of the Pratt & Whitney Bench Lathe



Figs. 30, 31 and 32. Examples of Early Lathe Beds having Narrow Guides

beds in 1900, embodied the narrow guiding strip in the design, and since that date its use has spread rapidly, not only as applied to lathes, but also as adapted to many other machine slides.

In the narrow-guide beds, the carriage or saddle is not in sliding contact with the vertical edge of the back shear, but has a clearance there, and is gibbed against the vertical edges of the front shear only. The only gibbing on the back shear is under its lip, merely to prevent lifting. As an alternative, the saddle may be guided by a raised strip

on the front shear, or by an underhanging strip, without affecting the principle. Sometimes the strip is raised above the general level of the bed surfaces, and sometimes it is formed by making a recess or channel in the front shear, although this is open to the objection that such a recess easily collects and stores the chips. The upstanding ledge, again, is more liable to become damaged.

Fig. 34 illustrates the Lang bed with its saddle. It is possible with this design to obtain a length of guide of as much as ten times the

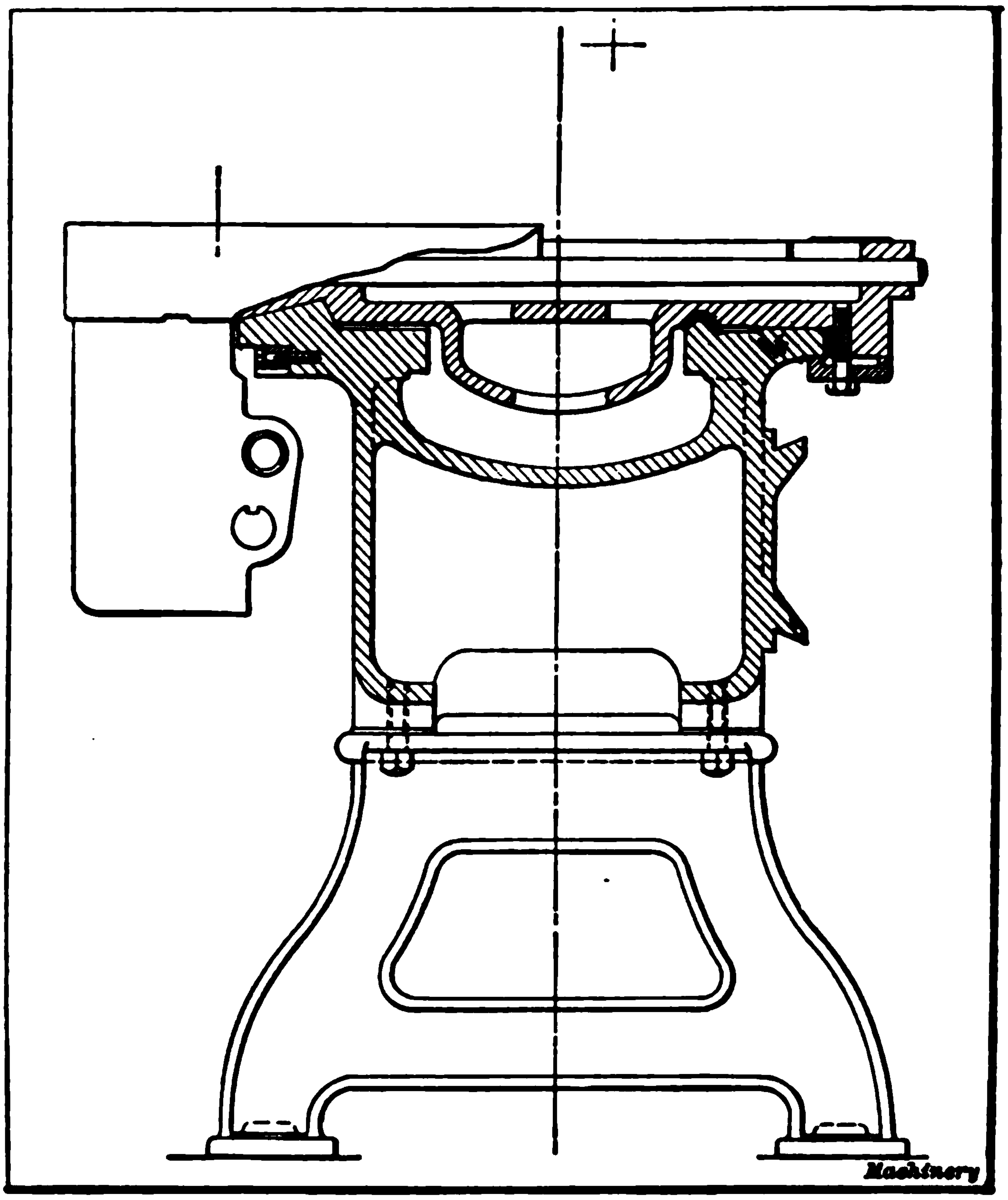


Fig. 33. The R. K. LeBlond Machine Tool Co.'s Design of Lathe Bed

width between the guiding surfaces, which has the effect of producing a very steady movement, with a much greater amount of freedom from twisting than is the case when the saddle fits on the outer edges of the shears. The setting-up of the tai can have no possible tendency to spring the sides as it might possibly have in the ordinary type c

In conjunction with the narrow guide, it bring the lead-screw as close as is practicab

the twisting tendency and friction caused by the old-style construction is minimized. Thus, the location of the lead-screw in Fig. 12 is just where it ought not to be with relation to the saddle slides, and this example of what was at one time standard English practice contrasts

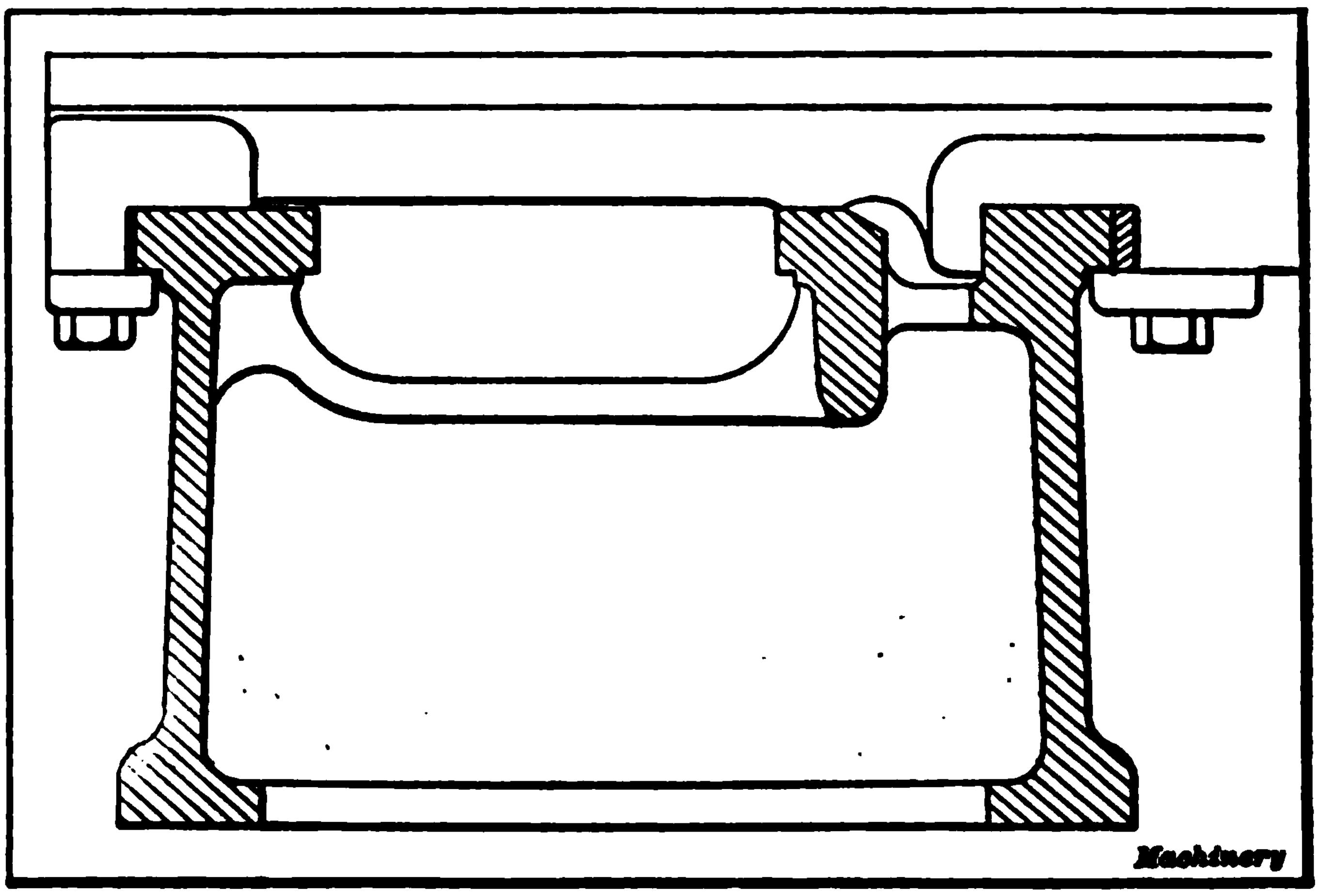


Fig. 34. The John Lang & Sons, Johnstone, Scotland, Type of Lathe Bed

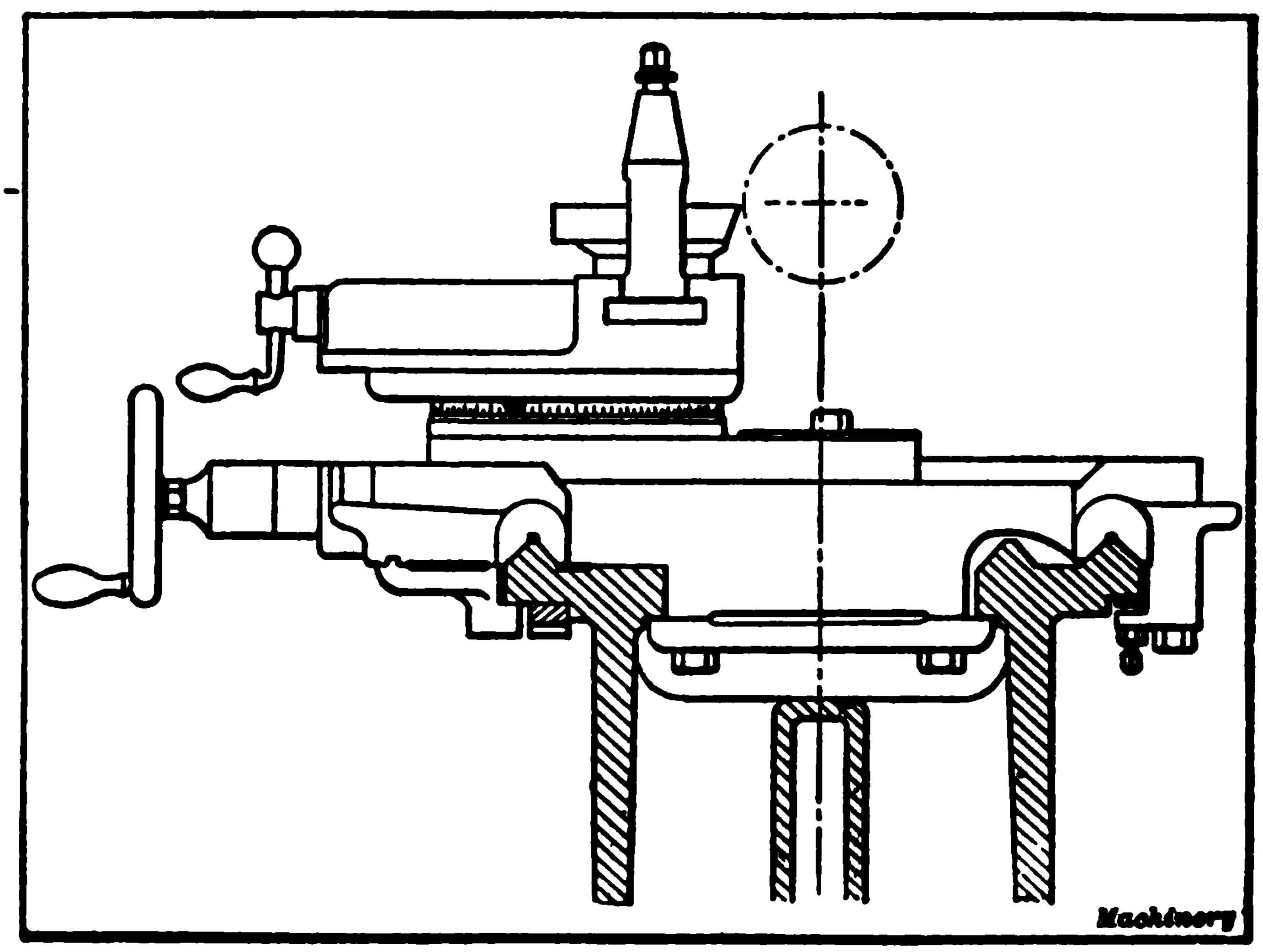


Fig. 35. The Lodge & Shipley Machine Tool Co.'s Lathe Bed with Supplementary Bearing Surface

unfavorably with the location of the lead-screw in Fig. 33 and some of the succeeding illustrations, where the force is applied at the correct place—near to the guide-ways. Experience shows that the narrow guide gives more accurate results than the usual design, and that the alignment of the saddle movement is preserved for a longer period.

American Designs Embodying the Narrow Guide Principle

Another important advantage, apart from the narrow guide itself, is that part of the pressure of the cut is resisted by a vertical face, and the forces tending to push the saddle off the bed are acting against this face, instead of against the back edge of the rear shear. This feature is also embodied in two American designs, by the R. K. LeBlond Machine Tool Co., and the Lodge & Shipley Machine Tool Co., both of Cincinnati, Ohio. In the former company's design a nearly vertical face is employed on the front shear, and in the latter's design the vertical inner edge of the front shear comes in contact with the carriage. The LeBlond lathe, Fig. 33, is not provided with a rear vee, the carriage sliding on a flat on the back shear, but in the Lodge & Shipley lathe, Fig. 35, the carriage fits on the usual rear vee, and in addition has a horizontal bearing on the surface adjacent to the front vee, so that the solid metal of the carriage is well supported.

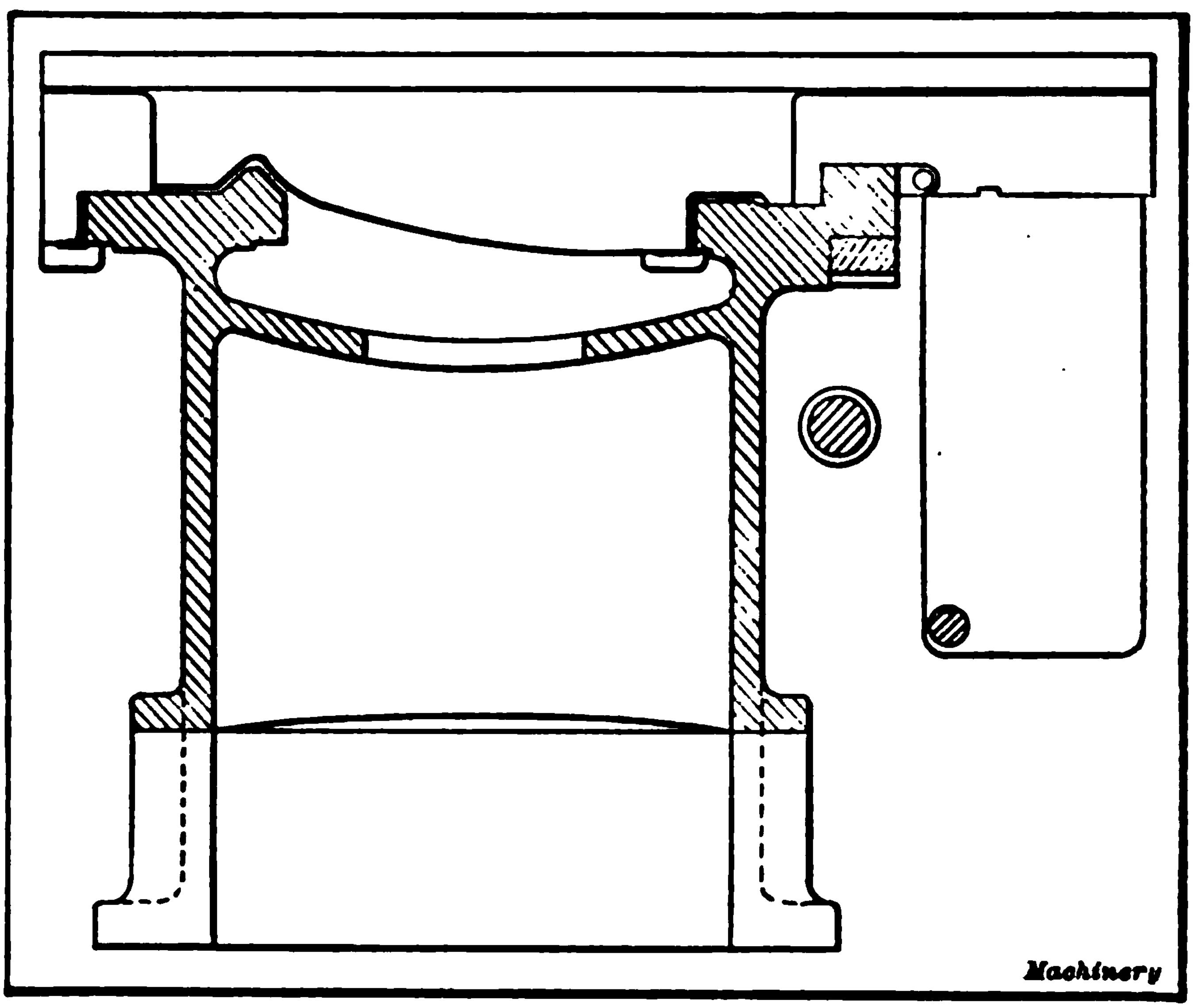


Fig. 36. Belgian Design of Lathe Bed with Raised Narrow Guide as used by Le Progres Industriel Societe Anonyme, Loth near Brussels

The firm of Le Progres Industriel, Societe Anonyme, of Loth, near Brussels, who has been engaged in lathe manufacture for many years, utilizes, in its present design, the narrow guiding principle, in conjunction with a single vee for the guidance of the tailstock. The carriage, as indicated in Fig. 36, does not touch this rear upstanding vee, and there is a clearance at the rear vertical edge of the rear shear. The adjustments are made by a wedge strip on the front edge of the front shear and by the two gib strips each underneath the lips. This design is a sort of compromise between American and English designs, and is used on large and small lathes alike.

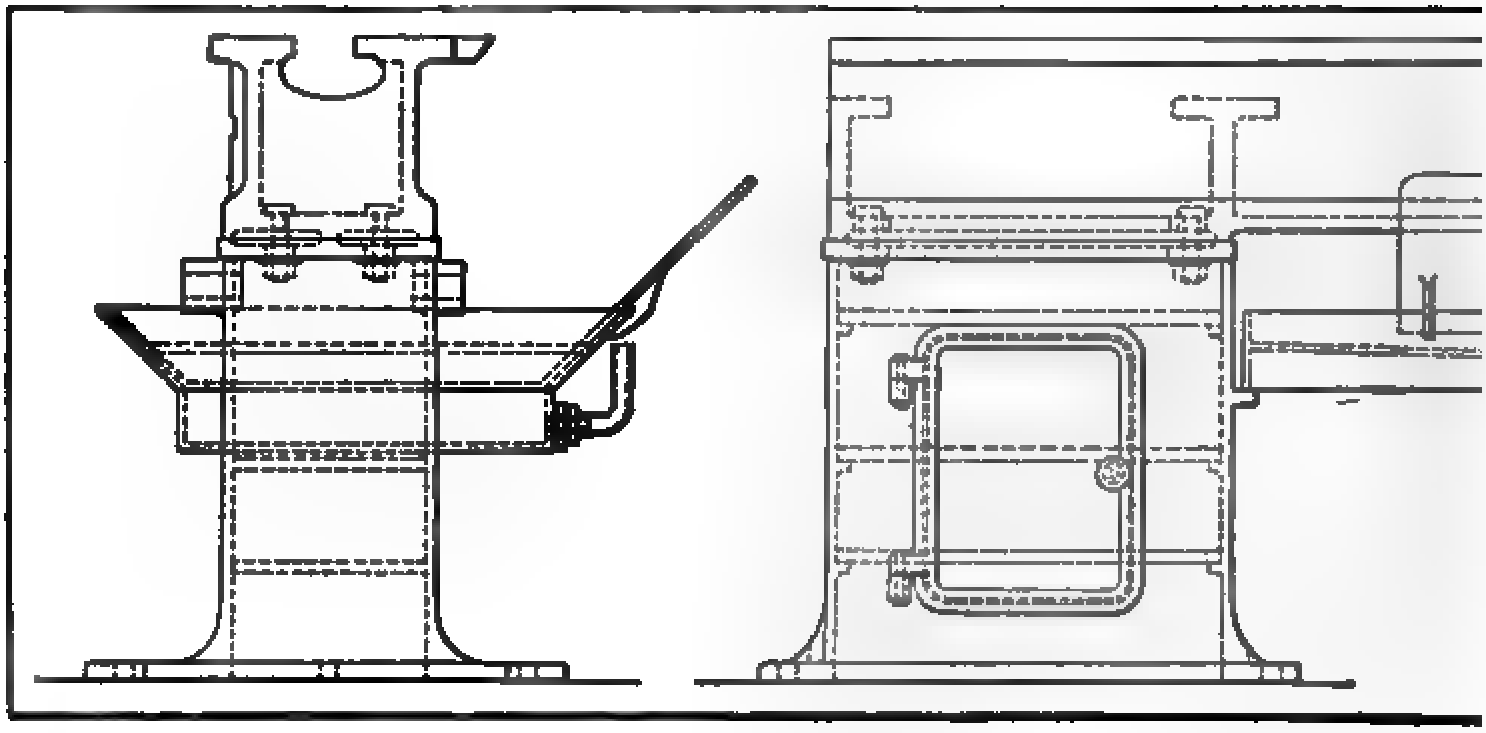
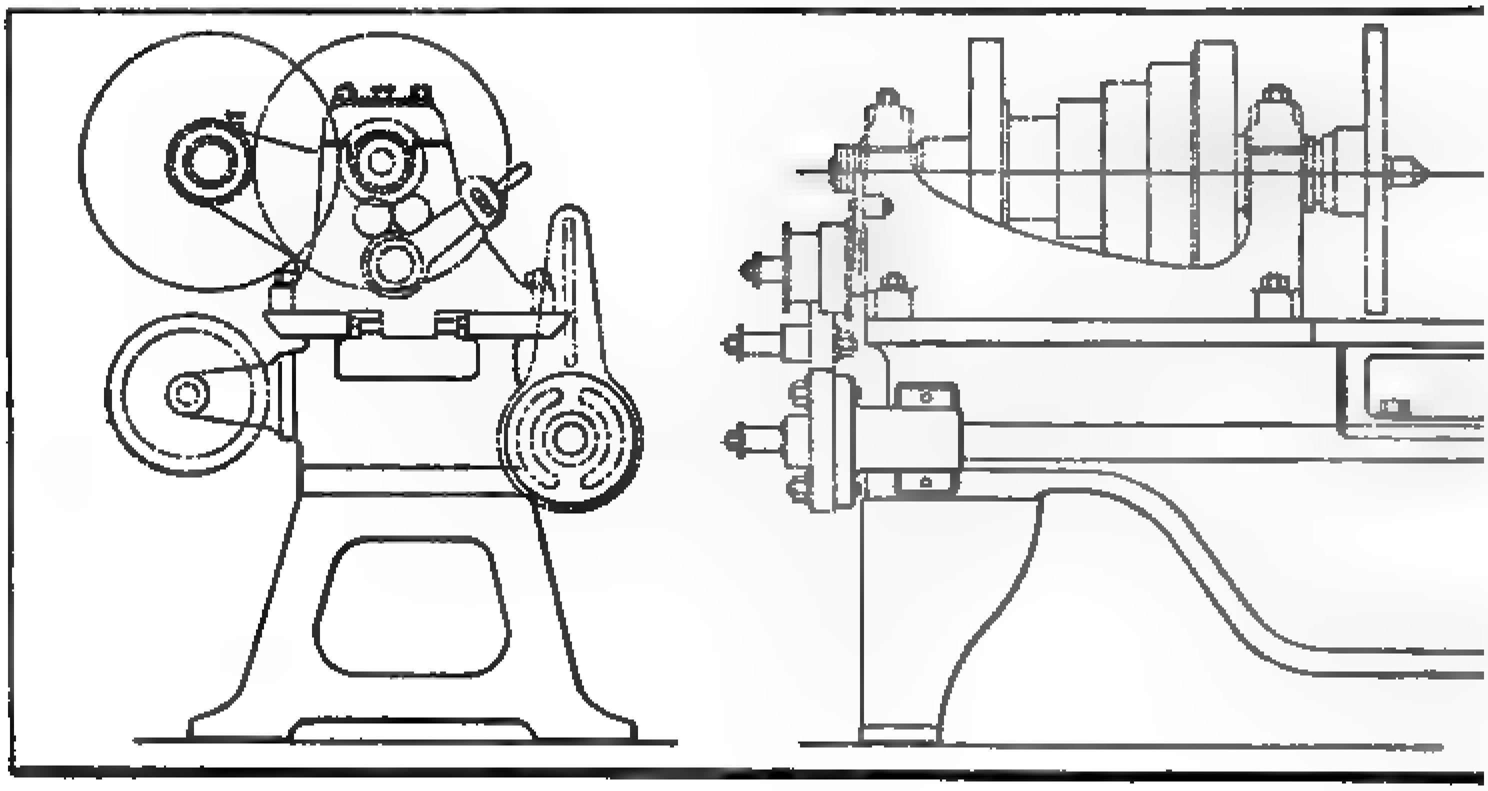


Fig. 27. Lathe Bed supported on Cabinet Stan



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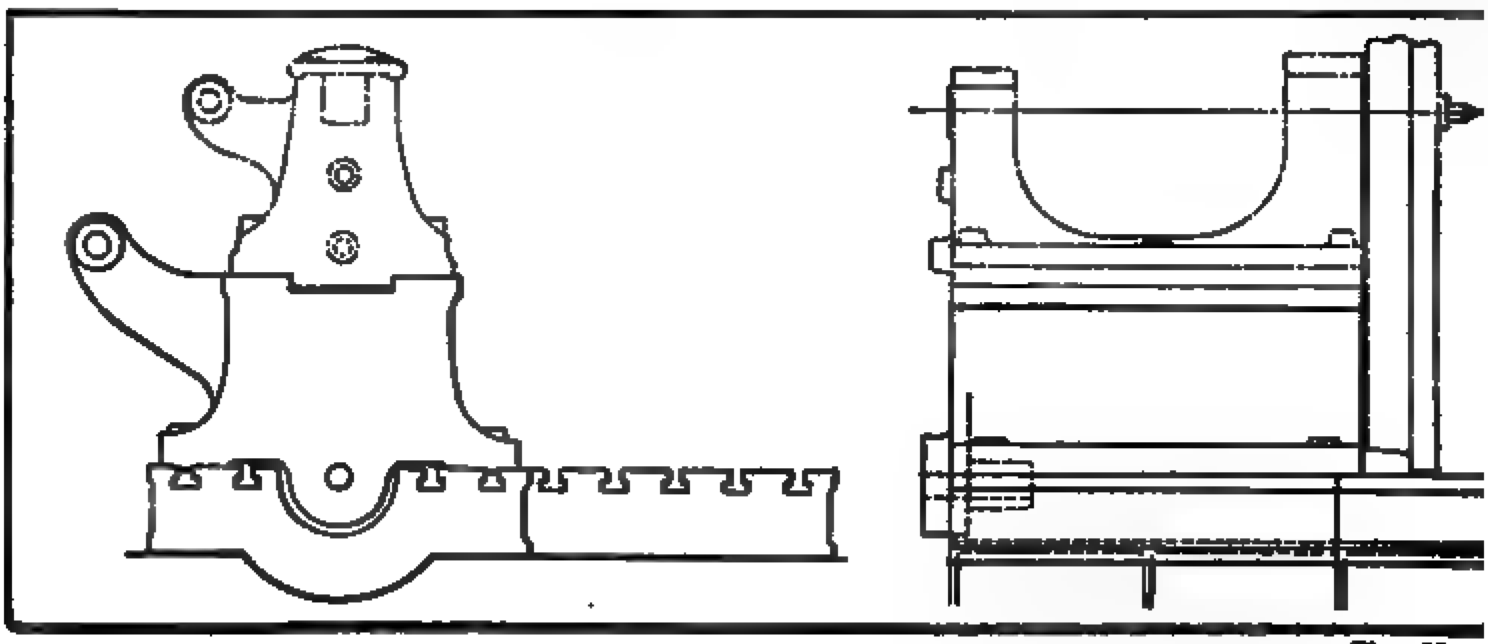
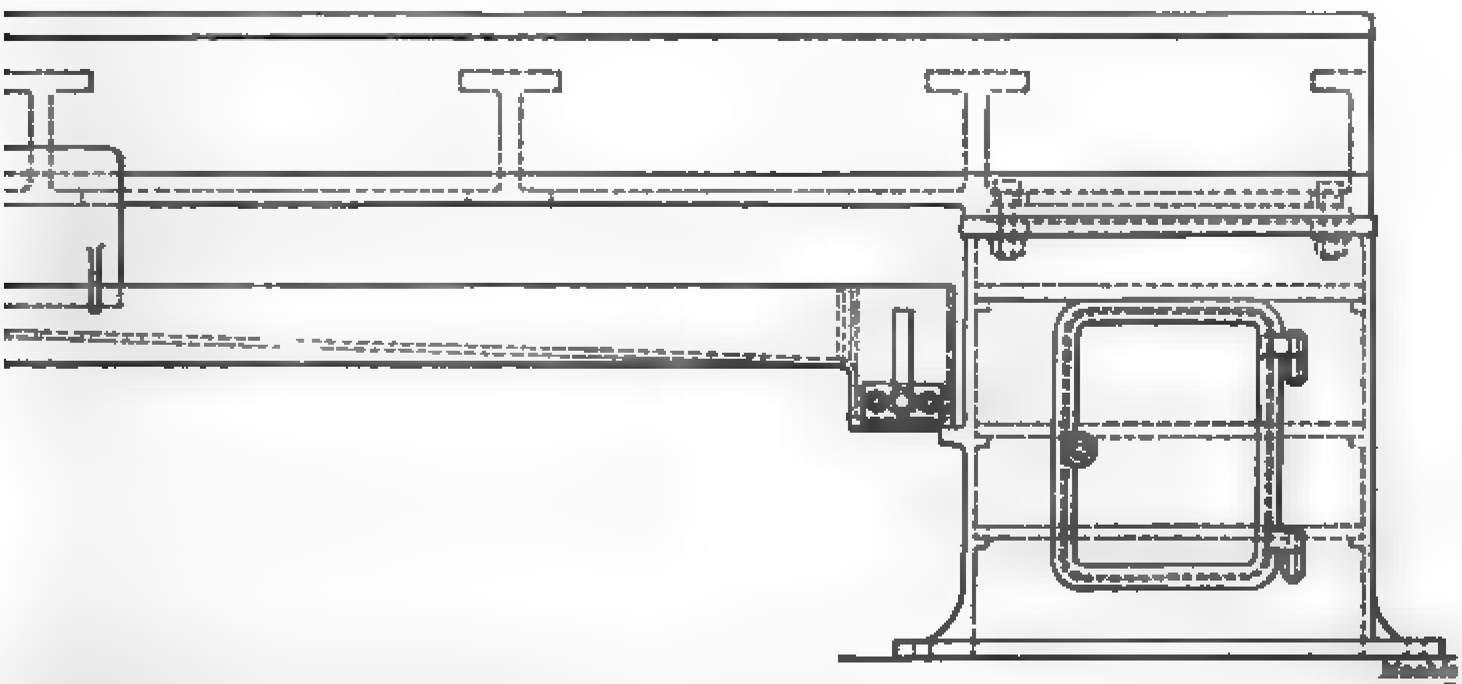
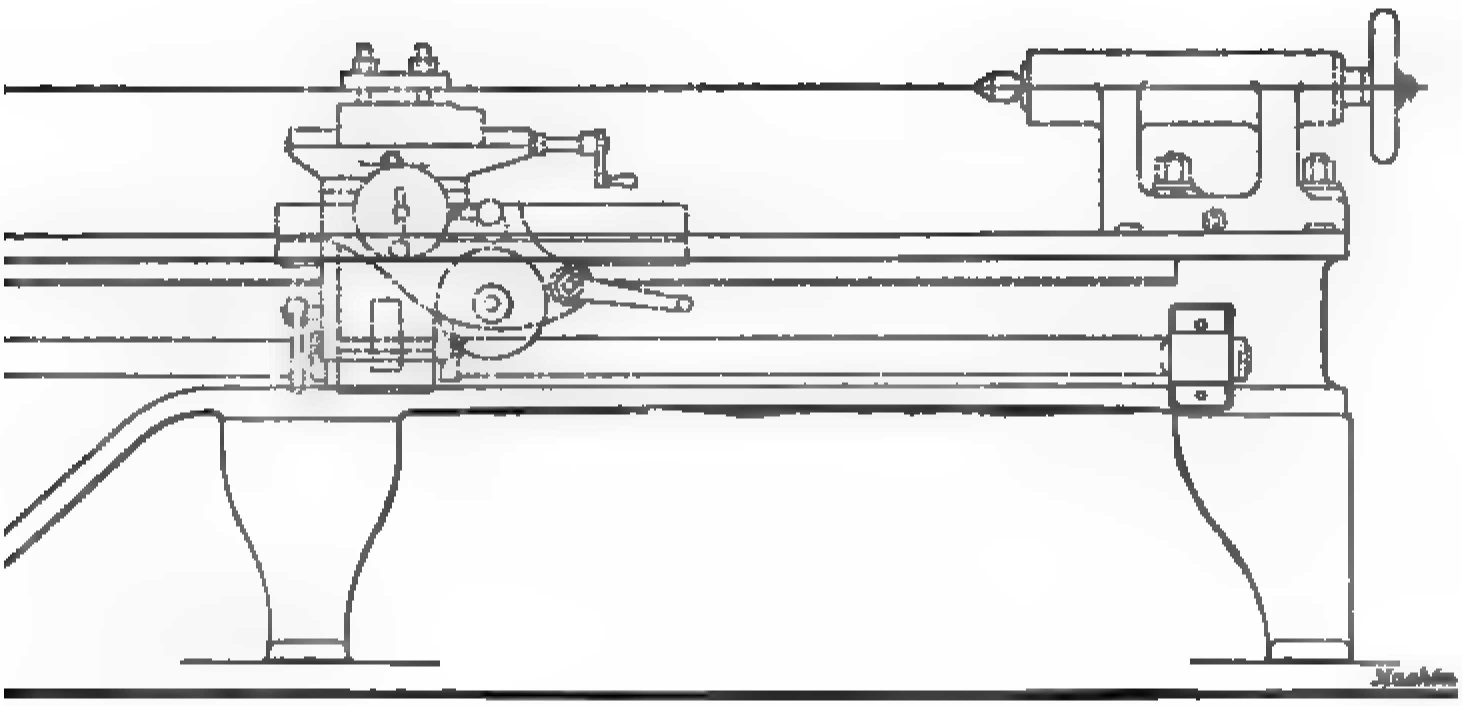


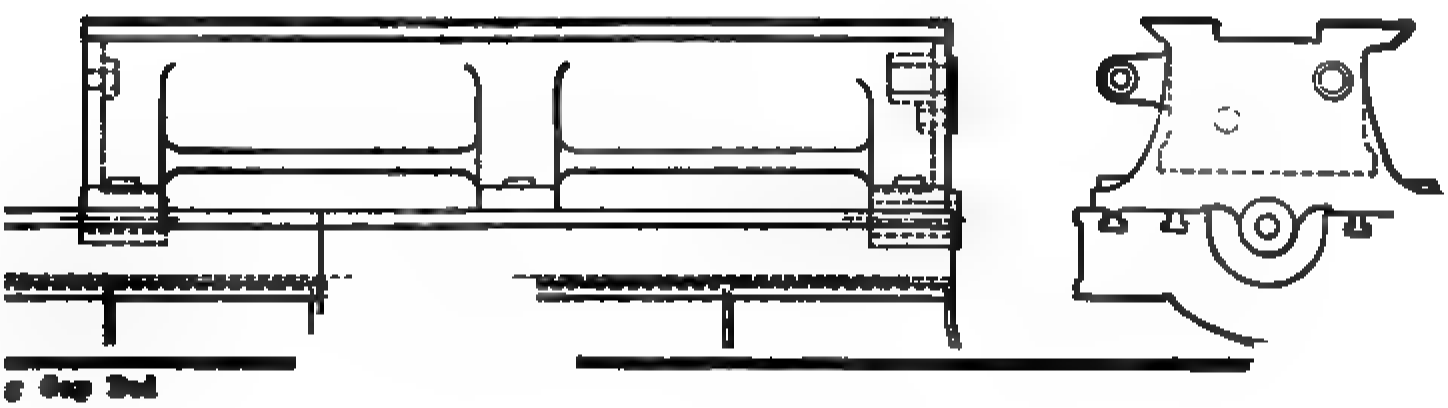
Fig. 29.



g with Provision for Lubricating the Cutting Tool



ed on Three Legs



g Gap Bed

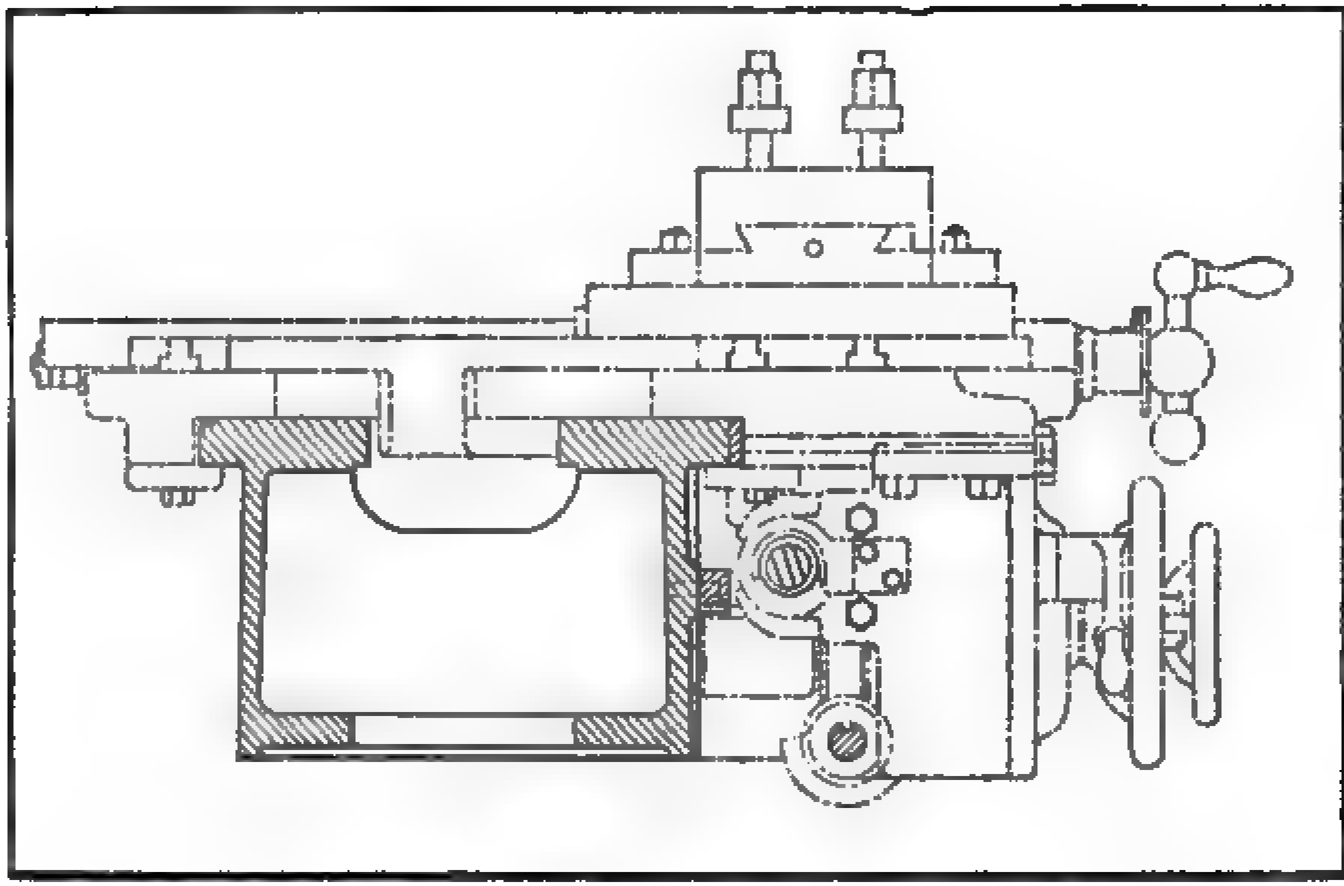


Fig. 40. Example of Narrow Guide on Front Shear of Lathe, designed by John Stirk & Sons, Ltd., Halifax, England

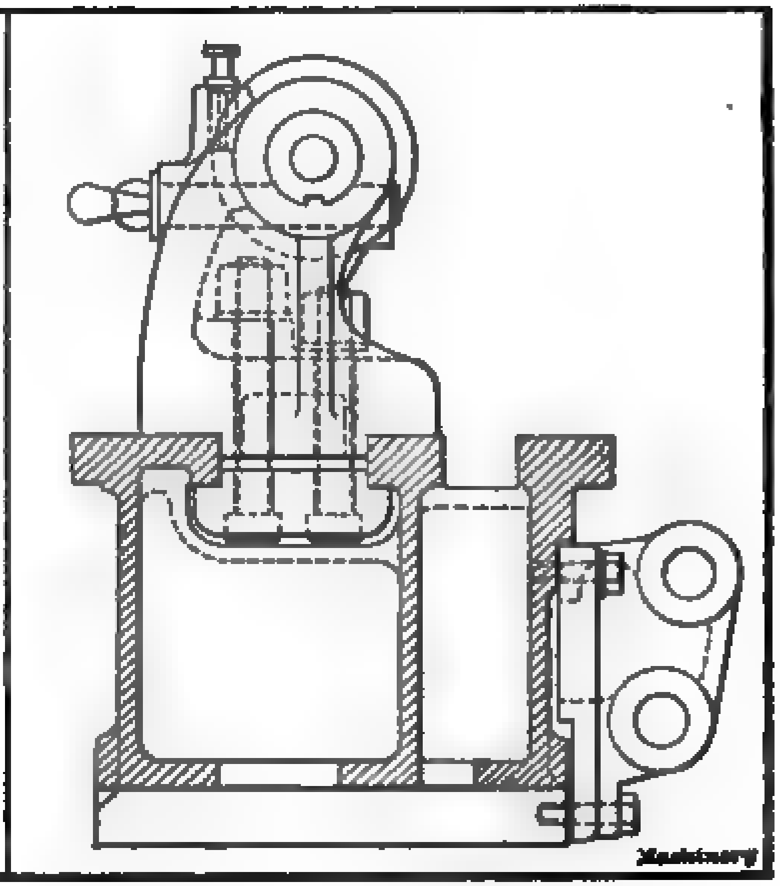


Fig. 41. Method of Fitting the Tailstock on Lathe built by Smith & Coventry, Ltd., Manchester, England

Several firms, instead of arranging a special strip for guidance, take the English bed as it is and utilise the front shear for the narrow guide, thus simplifying matters and obtaining an excellent support for the carriage just where it is most needed. Thus, Messrs. John Stirk & Sons, Ltd., of Halifax, England, have adopted the method illustrated in Fig. 40. A strip is fitted against the front vertical edge, and the solid metal of the saddle fits against the inner face of the front shear. At the edge of the back shear there is a working clearance, and two gib strips are used as shown, to prevent lifting. It will be observed that the lead-screw is brought as close as possible to the guiding

way. In this design the proportion of length to width of the narrow guide is about 4 to 1, but, as mentioned previously, in some cases where a strip is employed, the proportion may be as high as 10 to 1. Some firms who retain the front shear for guidance, as in the example just referred to, lengthen the wings of the saddle to the right and left in order to increase the bearing length. The tailstock slides between these wings up to the main body of the saddle.

Another design of a new 20-inch high-speed lathe, made by Messrs. Smith & Coventry, Ltd., of Manchester, England, is shown in Figs. 41

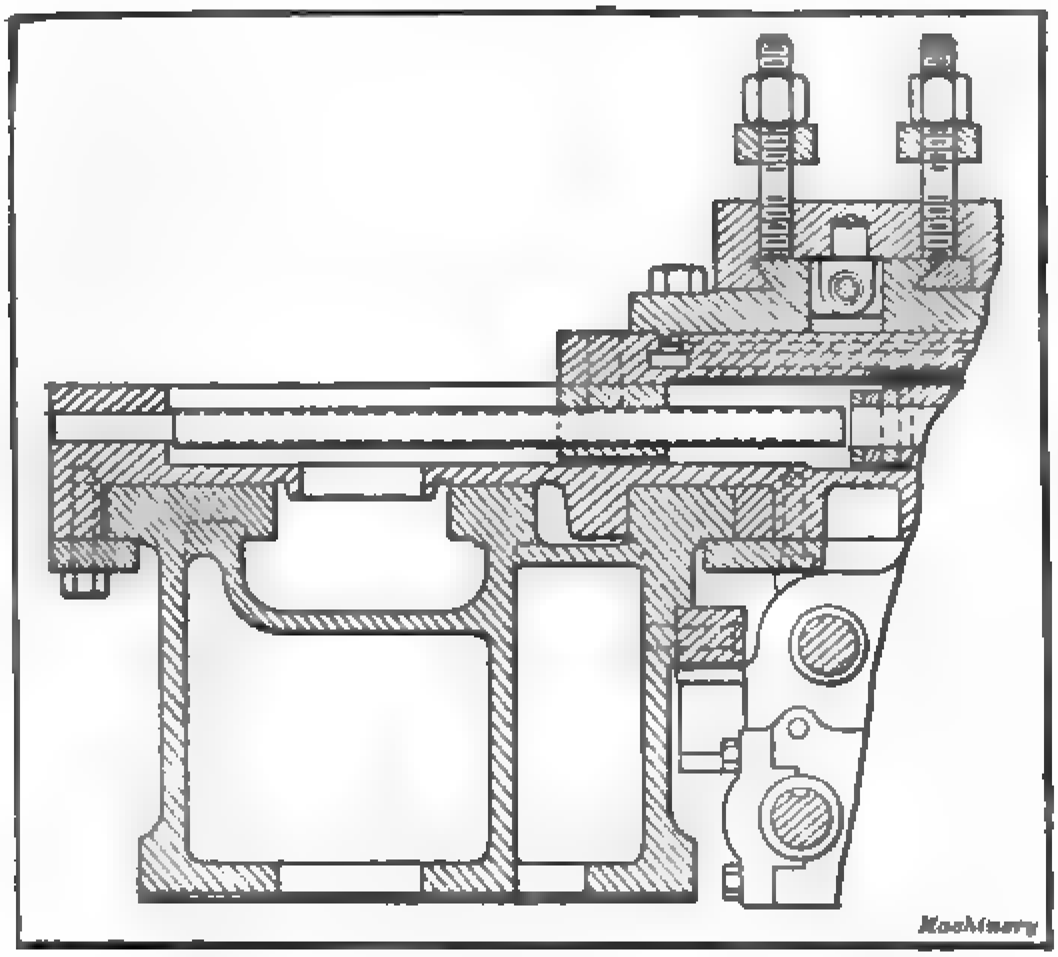


Fig. 42. Bed for 20-inch Lathe with Strip at Front, designed by Smith & Coventry, Ltd.

and 42. The two views here given illustrate the method of fitting the saddle and the tailstock. The front shear constitutes the narrow guide, with its take-up strip on the front face. The horizontal bearing is amply provided for by three ways; on the two at the rear the tailstock slides, as shown by Fig. 41. Gib strips are located under the front and rear edges.

Messrs. Ward, Haggas & Smith, of Keighley, England, fit their lathes with a narrow guide of the type shown in Fig. 43. This design is of the inverted type, the take-up strip drawing the saddle against the inside sloping face of the hanging lip of the front shear. These surfaces are thus out of the way of the chips, and a great proportion of length to width of bearing surface is secured. The lead-screw and rack are brought very close to the guiding area. Fig. 44 illustrates the method of tightening the tailstock by a clamping plate which presses against a sloping face on the inside of the rear way, thus draw-

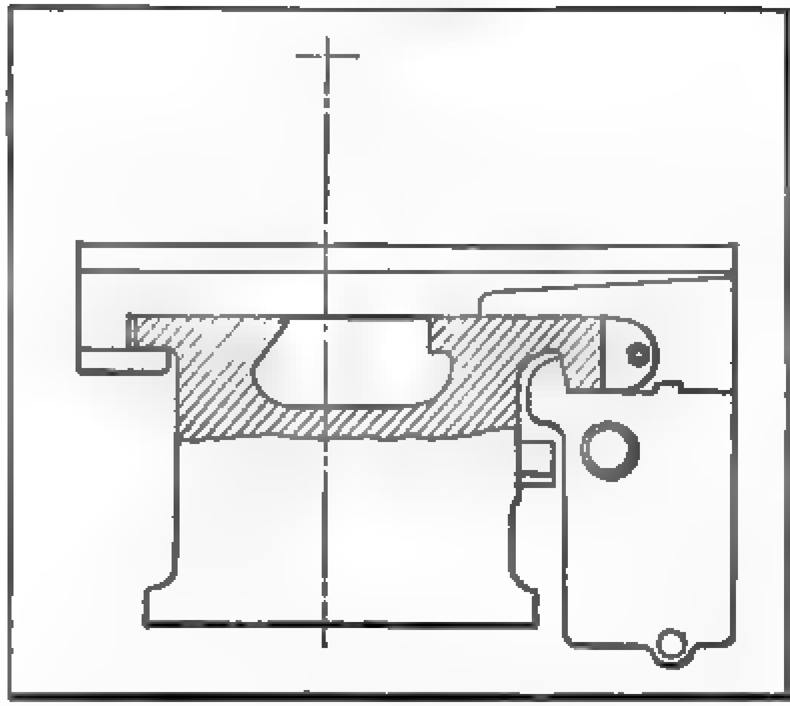


Fig. 43. Lathe Bed with Inverted Narrow Guide, designed by Ward, Haggas & Smith, Keighley, England

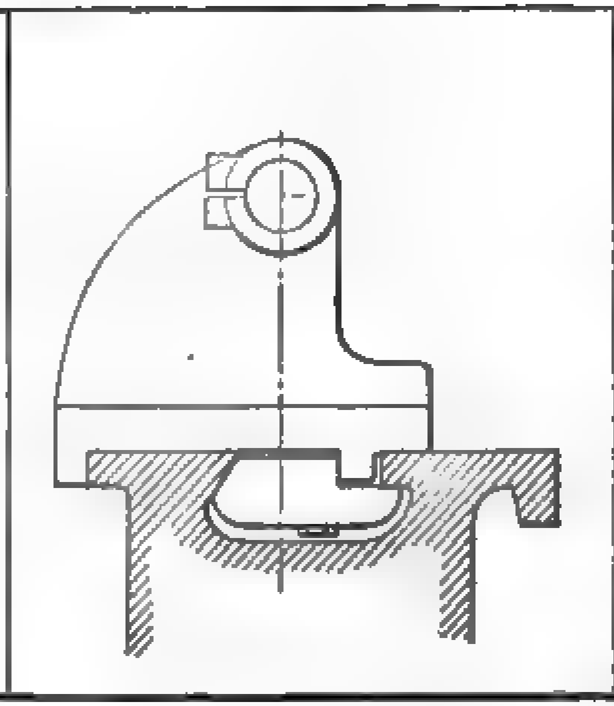


Fig. 44. Method of Clamping Tailstock to Bed shown in Fig. 43.

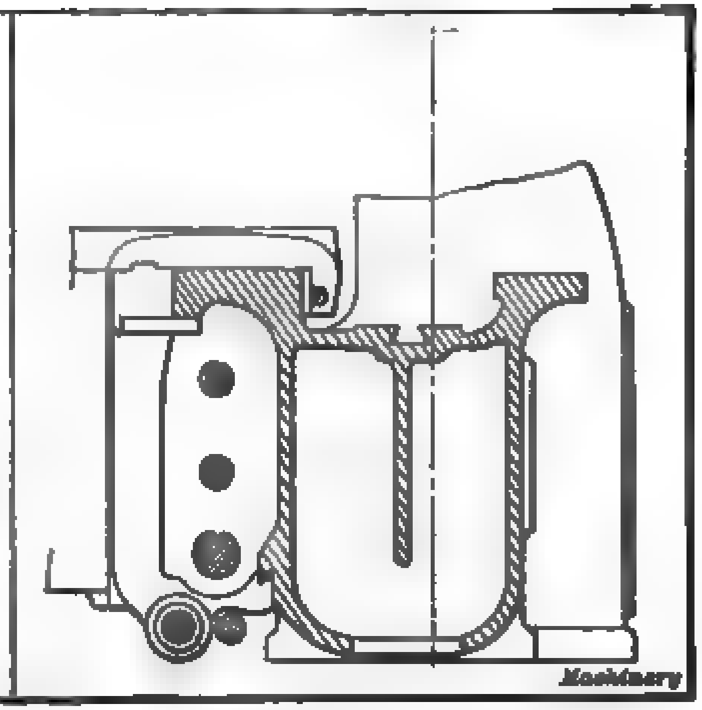


Fig. 45. Section of Bed of the Libby Turret Lathe, built by the International Machine Tool Co.

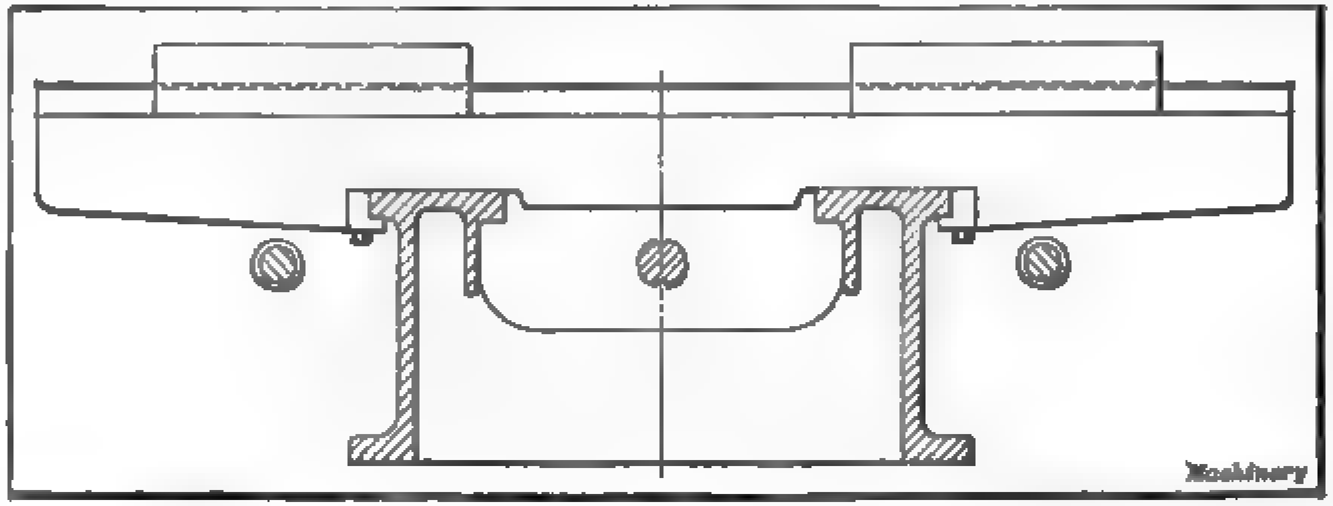


Fig. 46. Bed of Large Lathe with Internal Ribbing, as built by Hulse & Co., Manchester, England

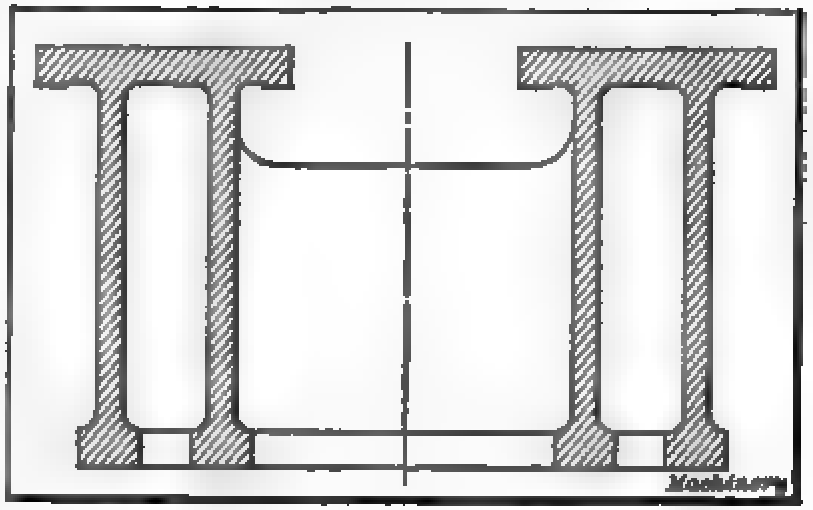


Fig. 47. Lathe Bed for Heavy Lathes with Double Webs

ing the tailstock against the back vertical edge of the shear. As this edge is not subjected to wear from the saddle, which clears it, the alignment is preserved indefinitely. Another example of an underhanging lip employed as a guide is that of the high-speed lathes built by Messrs. George Swift & Sons, of Halifax, England, as shown in Fig. 55, which shows the saddle without its apron.

In certain types of lathes one shear is employed alone to guide and support the carriage. This design is met with in a certain type of boring and turning lathe, where two duplicate carriages are run each on its own way, and are entirely independent of each other. A

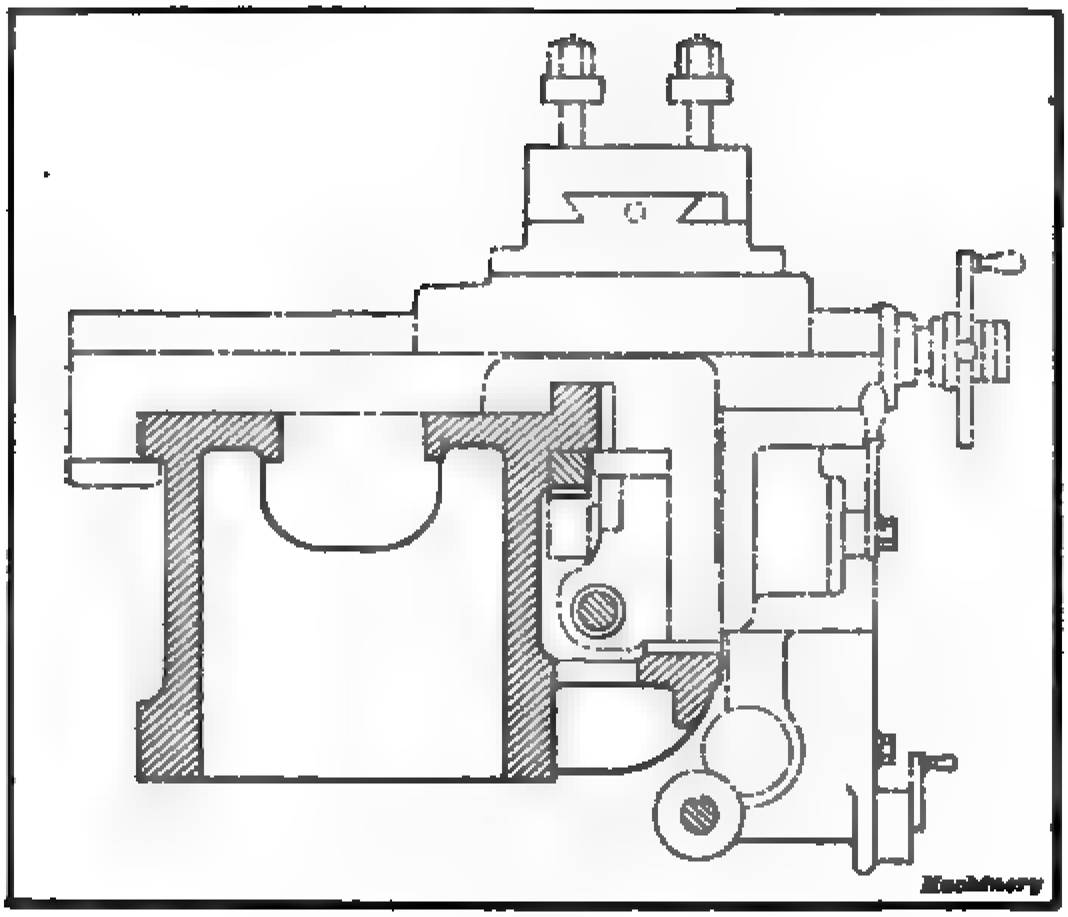


Fig. 48. Double-tier Bed with a Raised Narrow Guide on Lathe built by Darling & Sellers, Keighley, England

lower slideway or tier takes the overhang of the carriages. In another instance, that of the Libby turret lathe, made by the International Machine Tool Co., Indianapolis, Ind., the carriage fits over the front shear, as shown in Fig. 45, and a lower vee-guide opposes the tilting tendency of the carriage.

The principle of affording support to the carriage at some point situated below the general level of the bed surfaces is met with in several designs. One of the most successful examples is that of Messrs. Darling & Sellers, Ltd., of Keighley, England. A bed section of one of their lathes is shown in Fig. 48. The auxiliary or "lower-tier" bed is made in the form of a strong lip, projecting out from the front of the bed near the bottom. The saddle has a bearing on this, as well as on the top surfaces of the bed. The overhanging weight of the saddle is thus supported in a very satisfactory manner, and it will be seen that the actual effective width of the bed is increased

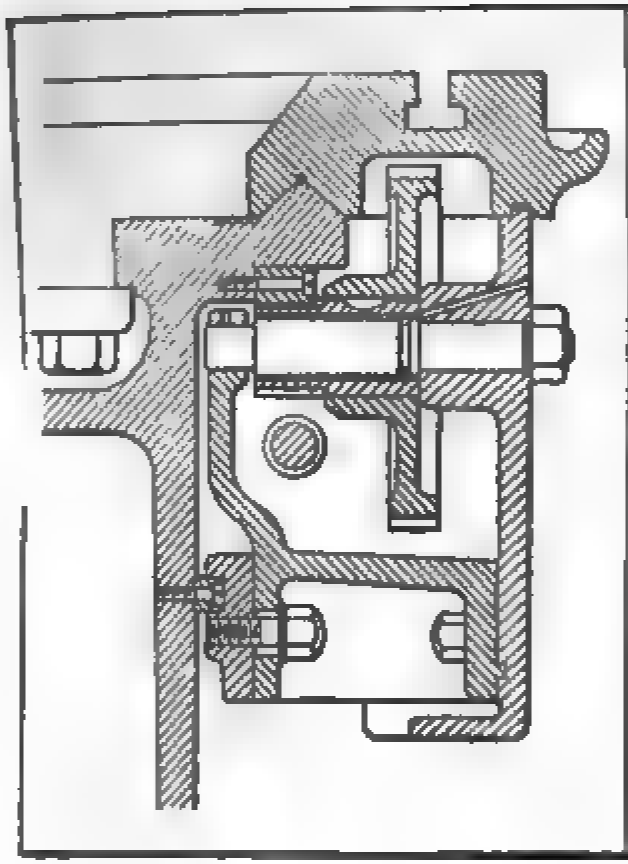


Fig. 49. Support for Apron on a Heavy Lodge & Shipley Lathe

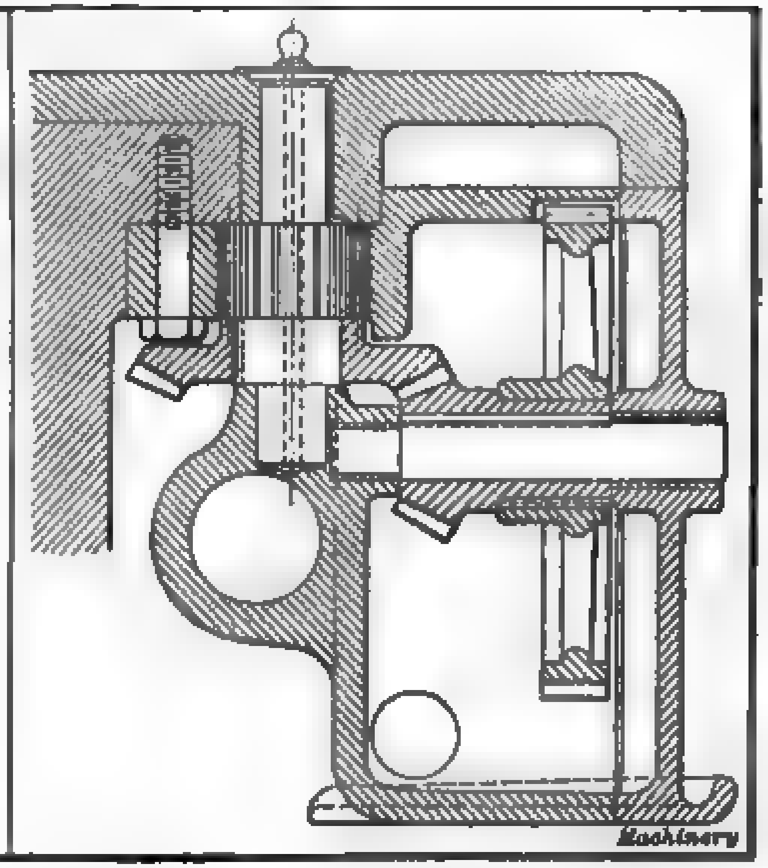


Fig. 50. Vertical Rack and Pinion on Lathe built by Joshua Buckton & Co., Ltd., Leeds, England

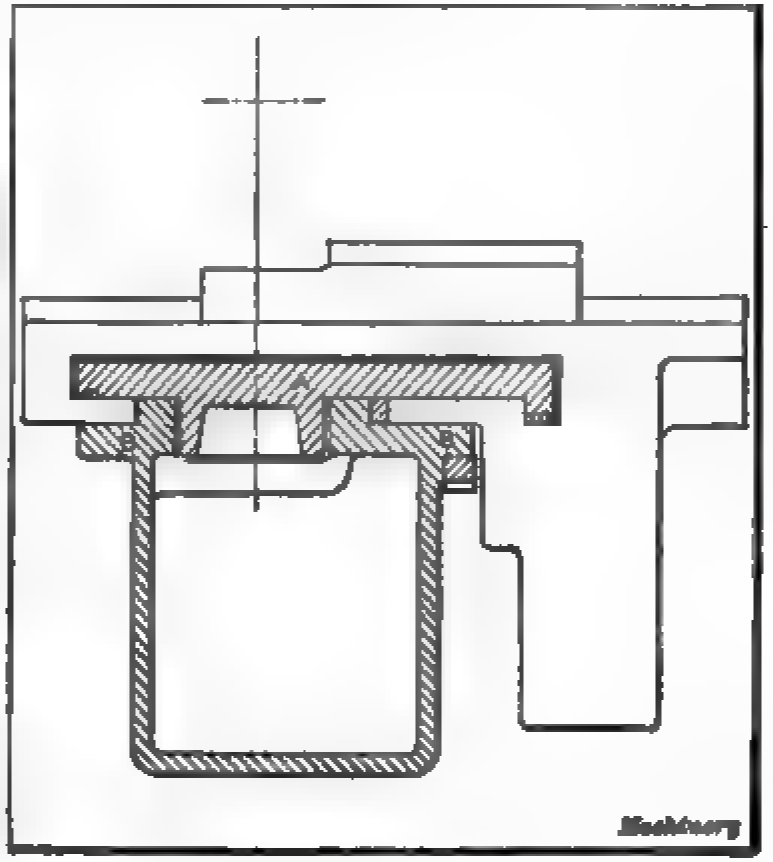


Fig. 51. The Protected Bed as made by George Richards, Ltd., London, England

over that of the normal or apparent width at the top. The advantage of this construction in turning large diameters, when the pressure is applied at the extreme edge of the bed, is obvious. The position of the lead-screw and rack eliminates undesirable twisting action. This bed is fitted with a narrow guide at the front edge, raised above the level of the bed as shown. A taper strip is used on the front face, and two gibs beneath the lips.

In Lodge & Shipley lathes of above 20 inches swing, a supplementary ledge is used, in the form of a steel strip let into and screwed to the front of the bed, as shown in Fig. 49. The back wall of the apron is supported by this

ledge, which helps to resist the forces tending to separate the gears and rack and pinion, while under heavy duty. With a similar object in view, some makers support the rack-pinion by the metal of the saddle, in order (see Fig. 5) to prevent the springing away of the pinion. Another device is to alter the position of the rack and pinion to a vertical location, and support the pinion shaft in bearings on both sides of the pinion. A design of this kind is shown in Fig. 50, showing the construction in a lathe made by Messrs. Joshua Buckton & Co., Ltd., Leeds, England.

A different kind of lower-tier bed is made by Messrs. Drummond Brothers, Ltd., of Guildford, England. This bed is employed for their

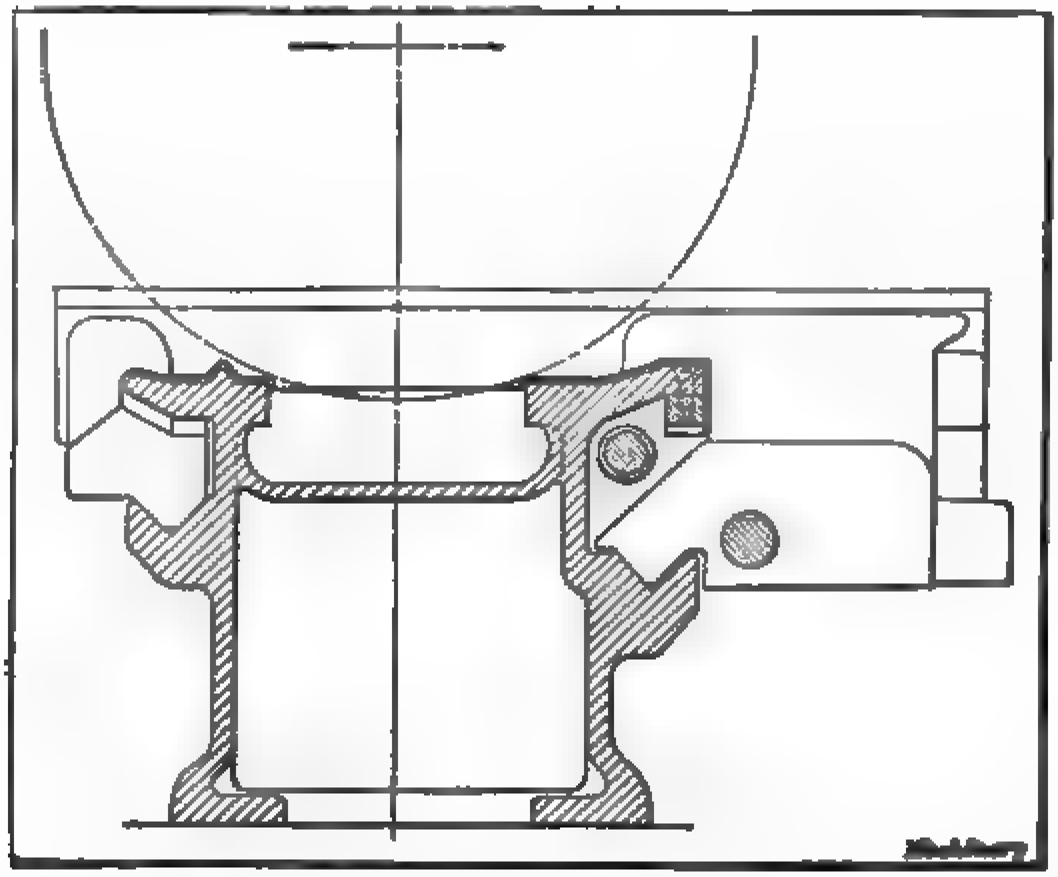


Fig. 52. Bed with Lower-tier Vee-ways as designed by Schaerer & Co., Karlsruhe, Germany

lathes having 15- and 18-inch swing. The gap is permanently open, and the saddle is guided by two lower tiers or slide-rails, so that it can be brought along on these past the gap and close up to the largest faceplate, with a minimum of tool overhang.

Another example of a lower-tier bed is that used in a lathe built by Schaerer & Co., of Karlsruhe, Germany, in which the advantages previously mentioned regarding the support of the carriage below the top level of the bed are obtained. There are two lower-tier vee-ways, as shown in Fig. 52, set at different heights (by which it is claimed that twisting is eliminated), and directly underneath the regular ways, so that chips cannot fall into them. The top of the bed is arranged with a vee and a flat to carry the headstock. The carriage has no bearing on the top, but only in the vee-ways. The position of the lead-screw and rack should be noted.

Methods for Protecting the Ways of Lathe Beds from Chip

A few instances are met with in which lathe beds are modified specifically for the purpose of protection. The bed is either cast of such a form that the slides come below the top surface, as in the example just noted, or extra covering plates or guards are fitted to keep the chips away from the bearing surfaces. A bed made by the London firm George Richards, Ltd., Fig. 51, has a top portion *A* which serves as a cover over the slides, and at the same time guides the saddle at the front, forming a narrow guide between its inner face and the outer front edge of the main bed. The surfaces *B*, on which the carriage slides are, therefore, absolutely protected from chips, and

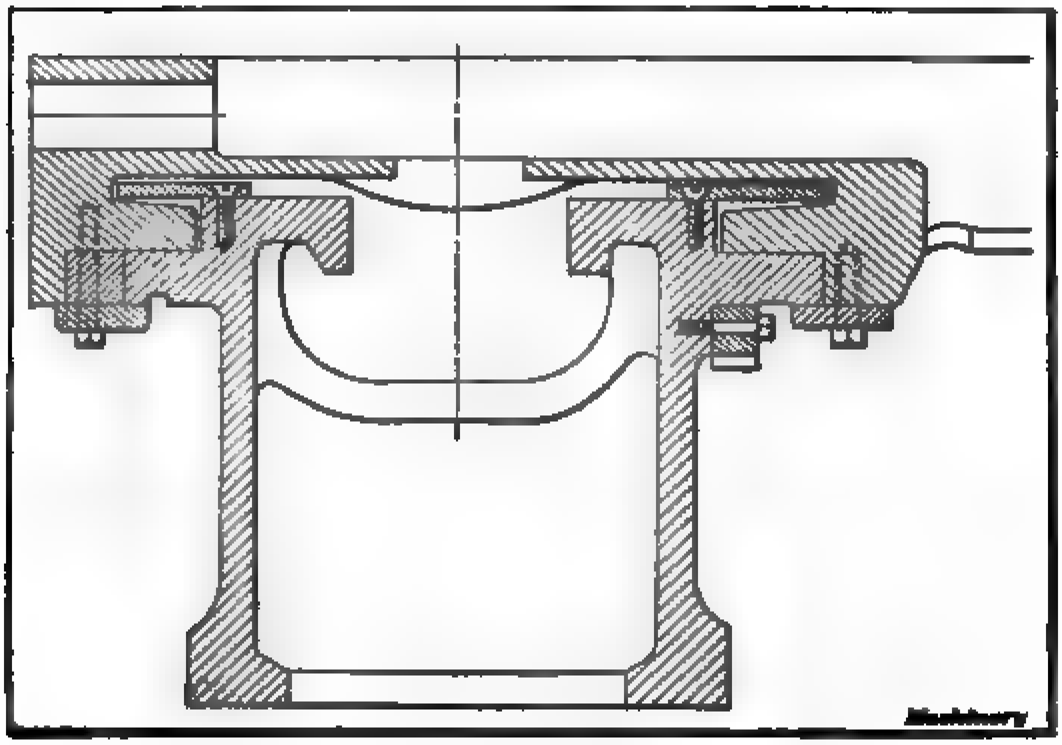


Fig. 53. A German Type of Lathe Bed with Guard Plates over the Slides

the lubricant does not become dirty. At the top of the portion *A* the saddle clears this casting.

Fig. 53 shows a German bed section which has the slideways arranged a little below the top surface. Steel covering plates, screwed on as guards, prevent chips from falling onto the ways. The tailstock slides on the top part of the bed, between the inner edges of the covering plates.

Messrs. John Lang & Sons build a range of surfacing and boring lathes (chucking lathes) without tailstocks, in which curved cast-iron guards, supported on short studs at each end, extend from the tail-end of the bed up to the chuck, so that chips cannot fall upon the flat ways of the bed, but are deflected by the guards and thrown off to one side. The section of a bed with its saddle cored to pass the guards, is shown in Fig. 54. It will be noticed that the saddle bears against the vertical edges of the front shear only, giving a narrow guide-way with a relation of length to width of about 7 to 1. The cross-slide (not shown) also fits on the same principle, being gibbed to the two edges of one slideway.

A rather curious type of bed is shown in Fig. 56. This type resembles an English bed at the back shear, but has a double "vertical" vee at the front edge. This lathe is made by H. Wohlenberg, of Hanover, Germany.

Double-way Type of Lathe Beds

Among the lathe beds which are made to but a limited extent are those of the double-way type, that is, beds with separate ways for the carriage and the tailstock. They are useful for work where it is required to move the carriage rapidly out of the way, and bring the tailstock up to the head without having to remove the carriage each time. The illustration Fig. 57 shows an example of this class, constructed by Henry Milnes, of Bradford, England. The tailstock slides on a back shear, below the carriage ways.

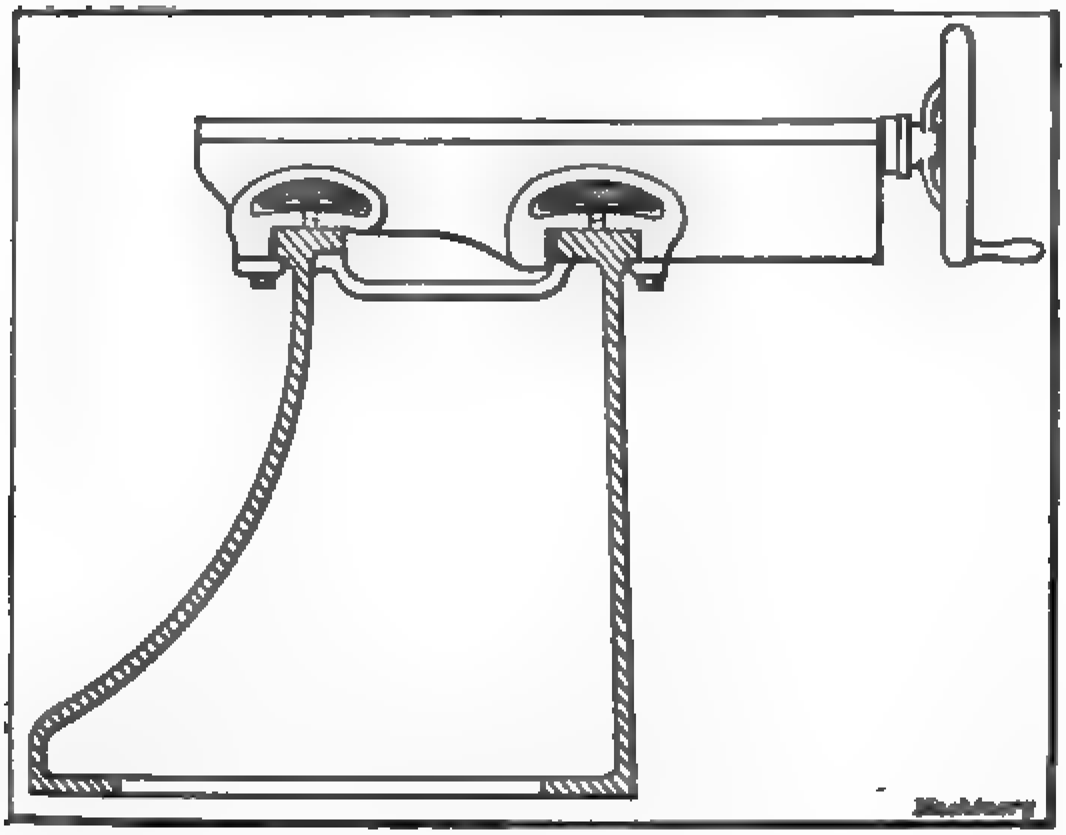


Fig. 54. John Lang & Sons' Lathe Bed with Covers over the Ways

A special type of double-way bed, Fig. 60, the speciality of Messrs. Dron & Lawson, Ltd., of Glasgow, Scotland, comprises a flat-topped way carrying the tailstock, the tongue of which has a tapered adjusting strip to maintain the fit in the groove, and a loose bed *A*, resting on two extensions *B* which project from the main bed. The auxiliary bed *A* can be swivelled on the extensions for taper turning, and can be adjusted to and from the centers. The slide-rest is carried on bed *A*, and is fitted by a narrow guide at the front. The slide-rest can be moved past the tailstock, and the center of the latter need not overhang. Motion is conveyd to the screw of the slide-rest, for feeding, through a universal-joint shaft, from the gear box in front of the headstock. Graduations indicate the amount of taper when the bed is swivelled. A similar principle is employed in the Niles lathes for turning printing-press cylinders, paper-machine rolls, etc., there being

sequent freed- vibration. By carrying the webs up between
the two bea 'ig. 73, the two bearings are firmly tied to-

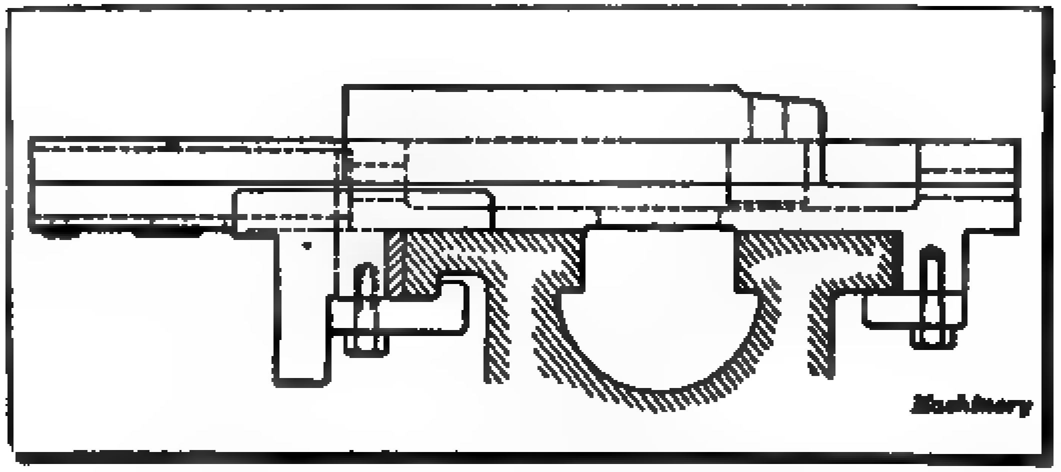


Fig. 55. Lathe Bed with Narrow Guide underneath Front Edge, built by George Swift & Sons, Halifax, England

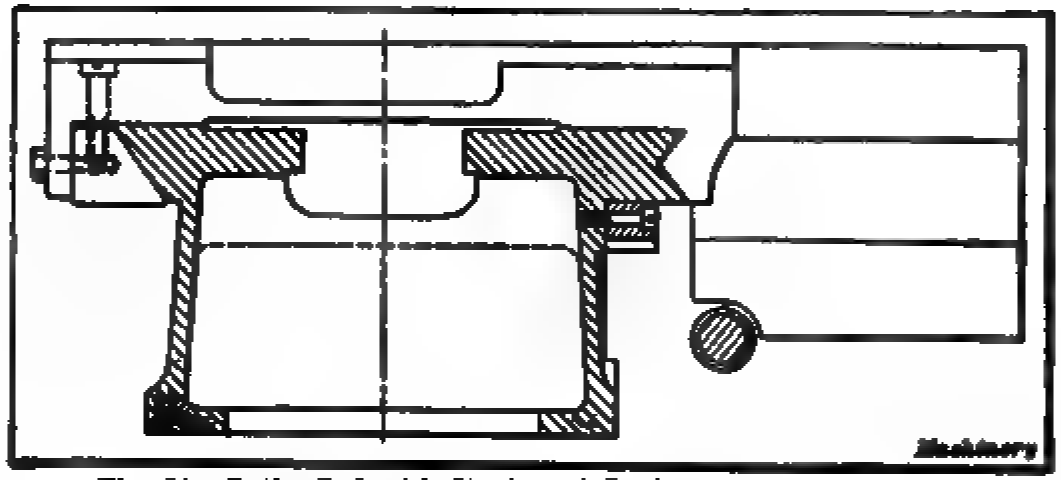


Fig. 56. Lathe Bed with Single and Double Vee-edges, built by H. Wohlenberg, Hanover, Germany

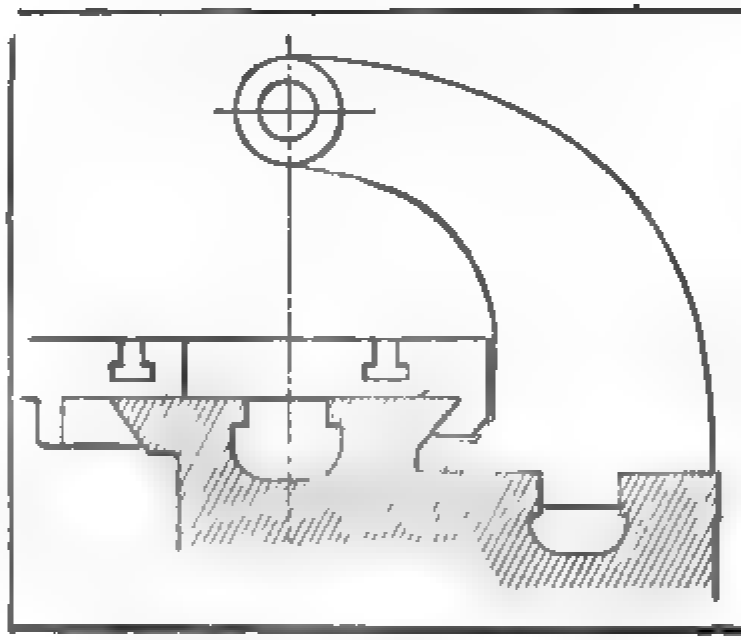


Fig. 57. Double-way Bed designed by Henry Milnes, Bradford, England

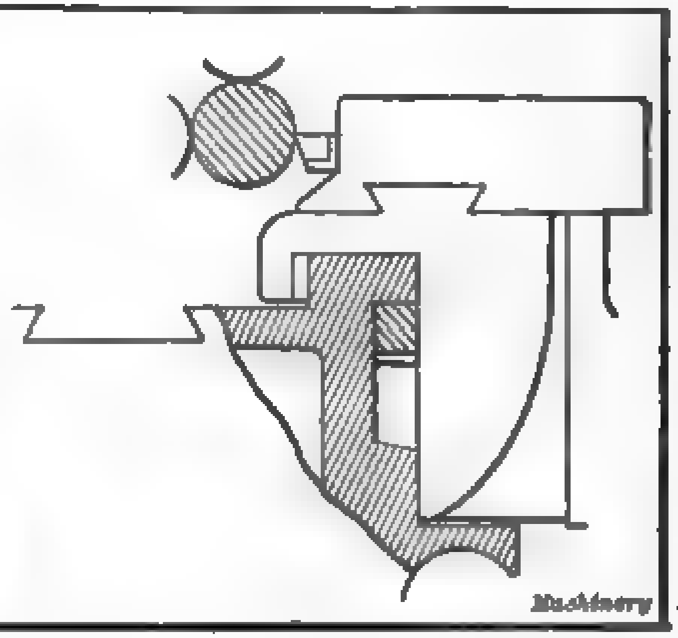


Fig. 58. The Fitchburg Mch. Wks. Design of Lathe Bed

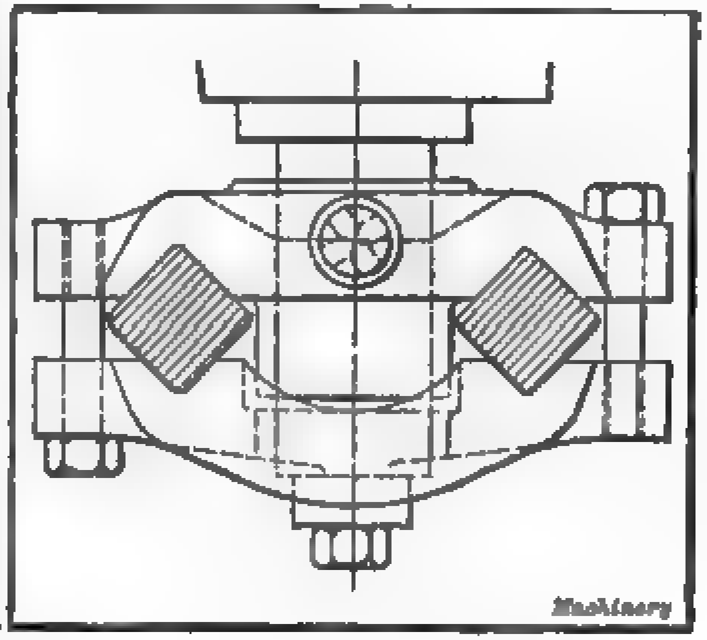


Fig. 59. The Bronet, Durenfouse & Cie Lathe Bed

carriages both at the back and front, sliding along supplementary beds or rails, which are themselves adjustable to and from the center.

The bed of the Lo-swing lathe (see Fig. 58), built by the Fitchburg Machine Works, Fitchburg, Mass., is an example of a special design evolved to avoid the built-up design of slide-rest in which the horizontal tool pressure acts at a point a considerable distance above the bed which has to resist it. This lathe, made for turning bar work between centers, has the tool-holder situated but slightly above the lip of the bed which takes the pressure.

As a final example of a special type of bed, the double square bar design, Fig. 59, is shown. It represents a type employed in France

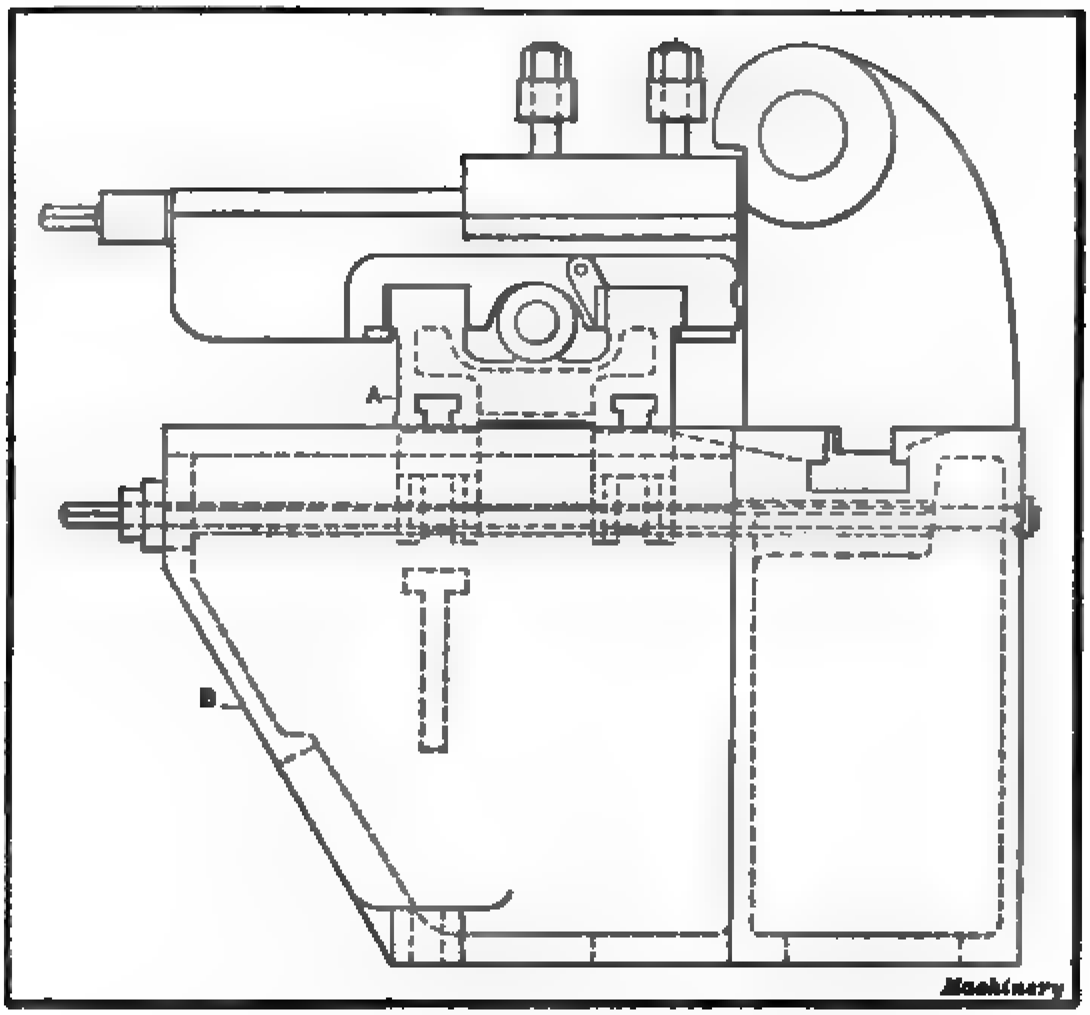


Fig. 60. The Dron & Lawson, Ltd., Glasgow, Scotland, Lathe with Extensions carrying Supplementary Bed for Carriage

for screw-cutting lathes, operated by hand, all the principal parts, including the bars, being of hardened steel and ground. The slide-rest fits on the two bars, and is slid along them by means of a lever motion. The headstock is also clamped to the bars. This lathe is made by Messrs. Brenot, Buronfosse & Cie, of Paris.

Beds for Heavy Lathes

When comparing the sectional forms of beds for large lathes with those of the ordinary type for the smaller and medium-sized lathes, the principal differences are found in the extra strengthening and stiffening of the large beds, in addition to differences in the form and number of their slideways, and in the building up and jointing

of the sections, which for manufacturing reasons sometimes take the place of a single large casting. Extra ribbing or webbing is one of the first changes introduced as the sizes of beds increase, as shown in Fig. 46, where webs are carried down on the inside from the top, and in Fig. 47, where the inner ribs completely duplicate the outer webs. Many variations of this type exist, which it is impossible to illustrate here. It may be mentioned that the bed in Fig. 46 is from a large lathe by Messrs. Hulse & Co., Ltd., of Manchester, England, provided with the firm's non-rotating twin lead-screws. There is one screw on each side of the bed, as shown, so that the saddle is propelled in a perfectly even manner, without risk of twisting.

The number of ways is increased to three, four, and even more, in large beds, according to the design of saddles employed, and their number. Three ways, as shown in Fig. 61, are frequently employed

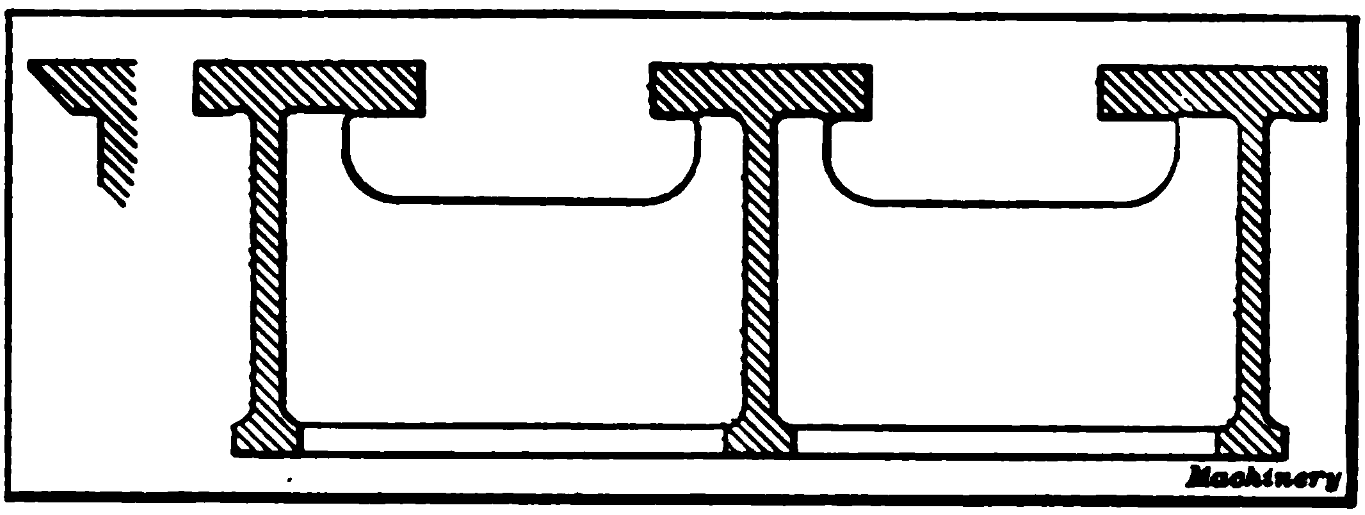


Fig. 61. Heavy Type Bed with Three Ways

when there are independent front and rear saddles, which fit on the front and back ways, respectively, and rest partly on the central one so that they may pass each other. The edges may be square or of vee form as indicated in the illustration. Beds with four slide-ways for two or more independent saddles are often used in place of the type in Fig. 61, in the larger lathes. The fitting of saddles and rests for turning large diameters on faceplate work introduces the use of wing or sole-plates, extending from the side of the main bed, or in some cases cast with it and provided with a slide-way. For certain functions, as in wheel lathes, a long cross-bed passes across in front of the face-plate, and is bolted to wings extending from the sides of the main bed. In any case, for turning large diameters, it is necessary to make the effective width of the bed sufficient to bring the tool-rests out to the required radius.

In some types of lathes for facing only, there is no bed at all, but only a stand to carry the headstock, and a T-slotted plate in front of this, which has no slide-ways, but which simply supports the tool-rest.

CHAPTER II

THE LONGITUDINAL FORMS OF LATHE BEDS

The remarks made in the previous chapter relative to the flexure and torsion of lathe beds need not be repeated here, but we shall consider, with the aid of the representative illustrations, how flexure is best resisted, and how the longitudinal shapes are modified to serve different functions. The principal differences which are made in the forms of beds are those arising from variations in dimensions, while subsidiary differences are produced by special designs of lathes, or additional functions, or by the particular class of work which is done in the lathe. Thus, the shapes of beds of similar dimensions for ordinary screw-cutting or engine lathes and those for turret lathes are very often radically different. In the one case provision has to be included for the screw-cutting and feeding devices, for the carriage motions, and for the tailstock, while in many turret lathes these features are absent, and the bed is plainer, with provision only for clamping the turret base and the cross-slide. On the other hand, the arrangements for lubricating the cutting tools and work often introduce complications into the design of turret lathe beds, and the casting is of a more elaborate character below the bed proper—around the top of the legs or standards.

The length of a bed has an important influence upon its construction and the number of supporting points, and if a gap is included, this also modifies the form to a considerable degree. The number of supports ranges from the single cabinet standard in some small lathes, and the two standards or legs in those of ordinary dimensions, to the three or more supports in longer beds. A continuous bed of full depth for the whole length is employed in lathes for heavy work and large swing, and is supported solidly on concrete foundations. The truth and rigidity of a lathe bed depends to a certain extent upon how it is fastened down. Ordinarily, beds are bolted rigidly to their foundation, which may be a wooden floor or a stone or concrete base.

Many years ago Prof. Sweet suggested the adoption of a tripod support for lathe beds, and this suggestion has been acted upon in practice. One end of the lathe is bolted down by the usual means, and the other is pivoted on a pin which passes through lugs in the bed and in the leg. The only support at that end is the pin on which the leg is free to adjust itself. Many firms also adopt the three-point support principle without any pivoting device: sometimes there are three points of contact with the foundation, and sometimes the bed is united to the legs at three points. The effect of an untrue foundation is thereby neutralized. Another method of affording good support is that of casting the bed with, or bolting it to, a single column of box form, which makes the lathe self-contained, and obviates

any risk of distortion or winding. This construction is employed both for small ordinary lathes, and for turret lathes up to fairly large dimensions.

Legs or Supports for Lathe Beds

When legs are used to support the bed, it is the custom of some makers to spread the legs under the head to a greater extent than those under the right-hand end, to resist the vibration, which is more pronounced at the headstock end. Other firms do not put ordinary ribbed legs at all under the headstock, but prefer a boxed cabinet support, even when there are legs at the other end. The principle of this seems faulty, since, if it is considered necessary to put a box support under the headstock end, the use of a flimsy support at the other end of a heavy bed appears unreasonable. Many makers view the matter in this light, and place the bed on equally solid and substantial supports at both ends; sometimes the supports are of identical pattern, but frequently they are a little larger at the headstock end, in order to afford more cupboard room for tools and appliances.

The practice of placing the supports a certain distance inward from the ends, mentioned in the previous chapter, is followed in many instances, and a further development of this principle is found in the case of some lathes, particularly those with gaps, where the metal of the boxed bed is carried down to a considerable depth under the headstock, gradually tapering off towards the ends. A great many turret lathes have their supports placed some distance inward from the ends of the bed, and the under side of the latter is often tapered or curved upward from the outside of the legs to the ends of the bed.

Gap Lathes

The question of forming a gap in a lathe bed has long been the subject of controversy. A gap lathe bed is practically as common in England as a straight bed. Theoretical considerations have been urged against it, chiefly on the ground that the bed is weakened, because its continuity is broken; but an English lathe maker would argue that the metal which is removed can be more than compensated for by extra metal placed underneath and beyond the gap, and in the heavier lathes by metal brought down to the ground in the form of a broad foot. The real objection to a gap is its unalterable dimensions—it is wider than is required for some jobs, and not wide enough for others. The fitting of the bridge-piece is also liable to become slightly inaccurate when a lathe has done much service, but this can be rectified. Thirty or forty years ago such lathes predominated over all others, but gradually, with the growth in specialization, they were displaced, to some extent, by straight-bed lathes on the one hand, and by regular facing lathes, and vertical turning and boring mills, on the other.

The movable gap is used to a moderate extent, in medium and large sizes of lathes, and would be adopted more extensively but for the fact of the ever-growing specialization. The breadth of gap is adjust-

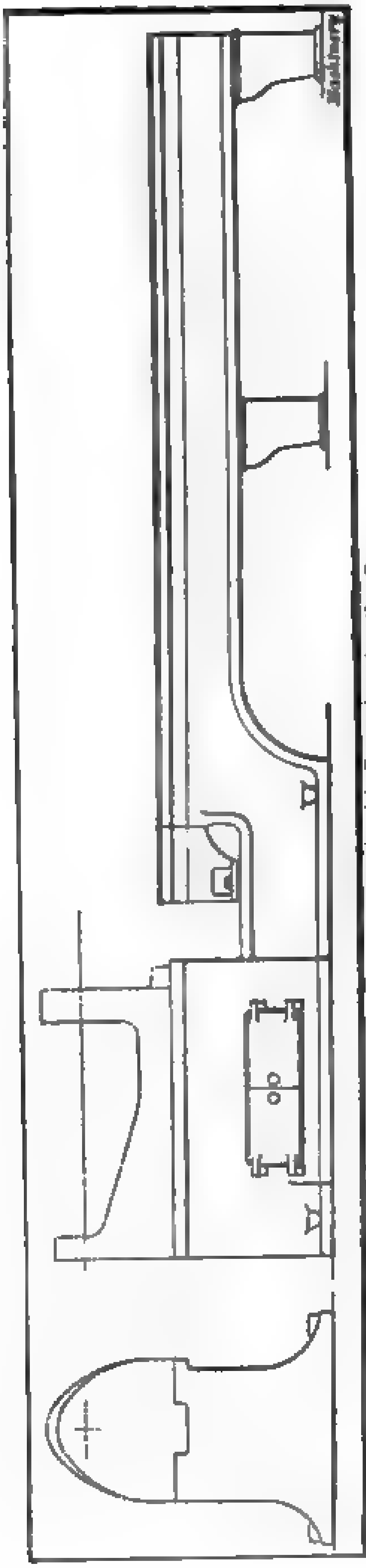


Fig. [illegible]. Gap Bed with Support under the Gap

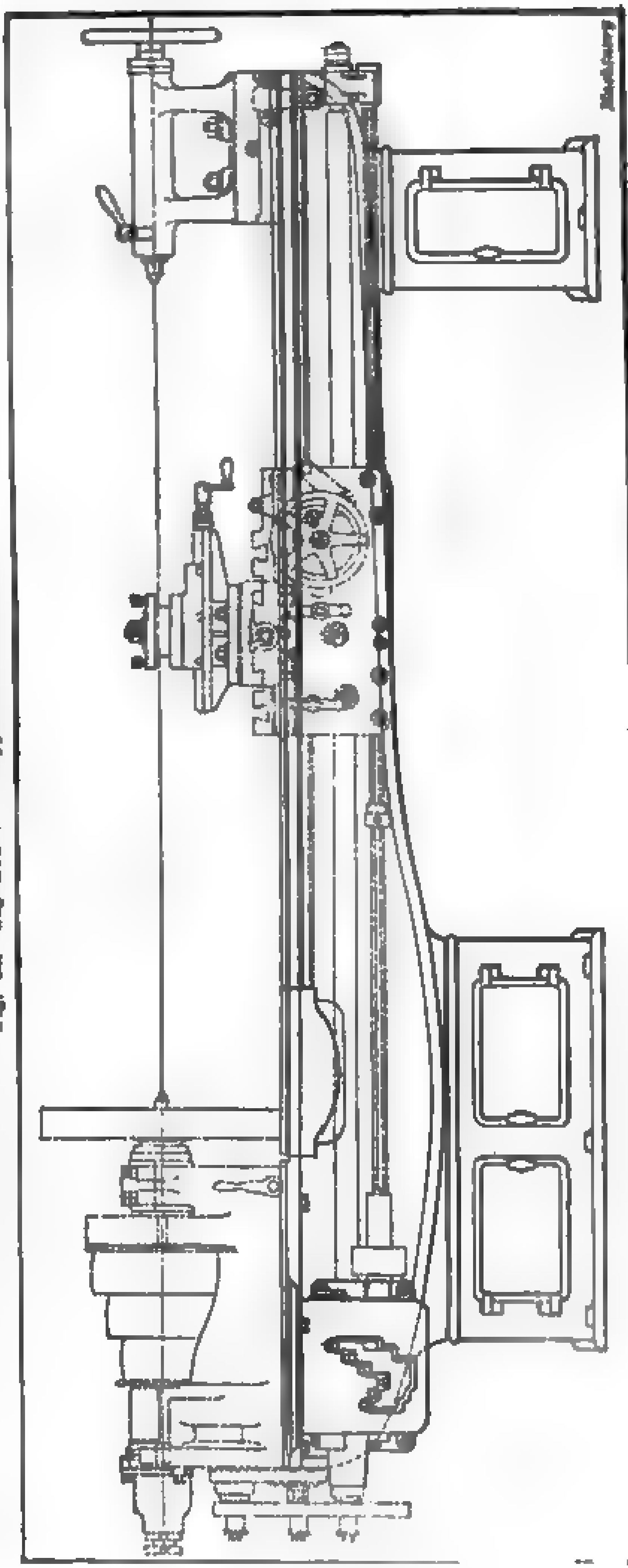


Fig. [illegible]. Gap Bed of French Design

able within a wide range, or it may be closed up entirely, the object being, of course, to support the carriage as close as practicable to the cutting point of the tool under all conditions. The most serious defect in gap lathes, perhaps, is the fact that the lead-screw has to be kept low down to be out of the way. In the movable-gap lathes another difficulty arises in the driving of the lead-screw, which has to be done from gears at the right-hand end of the bed.

Fig. 37 shows the form of a good type of bed, supported on box standards at both ends. The bed is equipped for the use of cutting lubricant or oil, though not in such a perfect manner as some beds shown later. A more elaborate type of bed for a 20-inch high-speed lathe, built by Smith & Coventry, Ltd., of Manchester, England, is

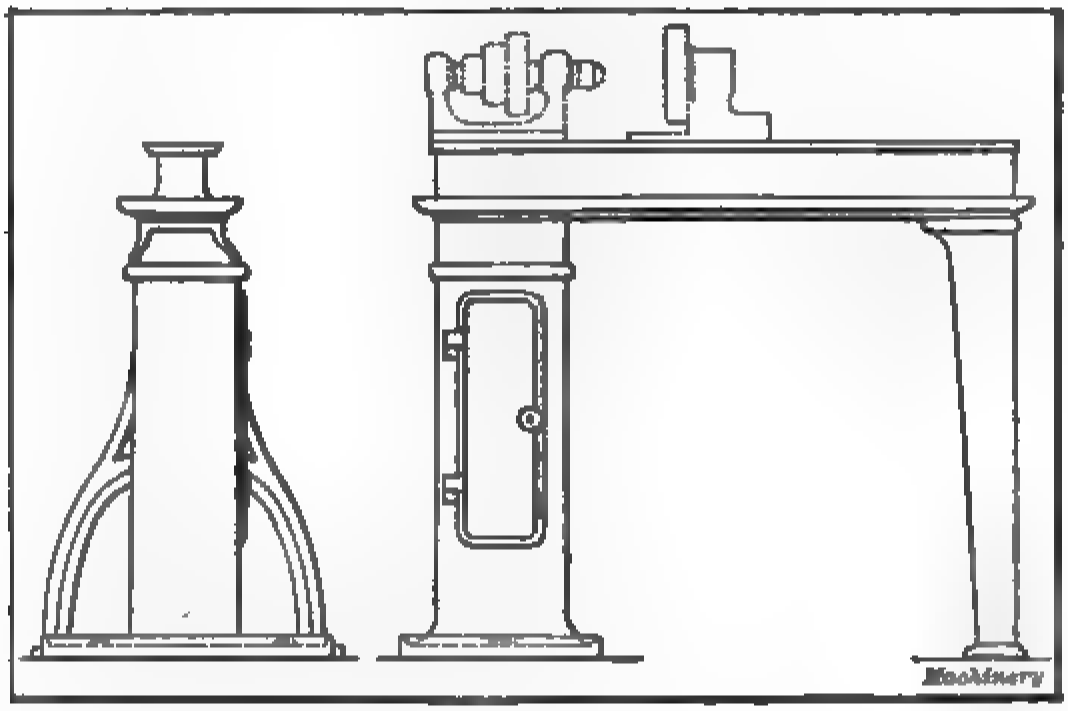


Fig. 64. Bed for Small Lathe

shown in Fig. 65. The cross-sectional shape of this bed is shown in the previous chapter. The details of the boxing and cross-ribbing and the joining of the bed to its standards will be observed. The right-hand standard is surrounded by an oil rim which conducts the lubricant into the trough, and at the top of the bed, close to the headstock, a space is left for the oil and chips to drop down into the trough.

The two principal designs of gap lathes are represented in Figs. 38 and 62, the first having the gap compensated for by the usual deepening underneath, and the other having a continuous base, such as is adopted for heavier lathes. In each case an intermediate leg is located under the bed, owing to its length. It will be noticed that in one case the gap-piece entirely fills the opening, while in the other it only partially does so, leaving a space for a large face-plate or chuck to remain in place, and still providing sufficient length for the support of the saddle.

Fig. 63 shows a French design of gap bed in which the metal is carried down in a graceful curve under the gap. The bed is well

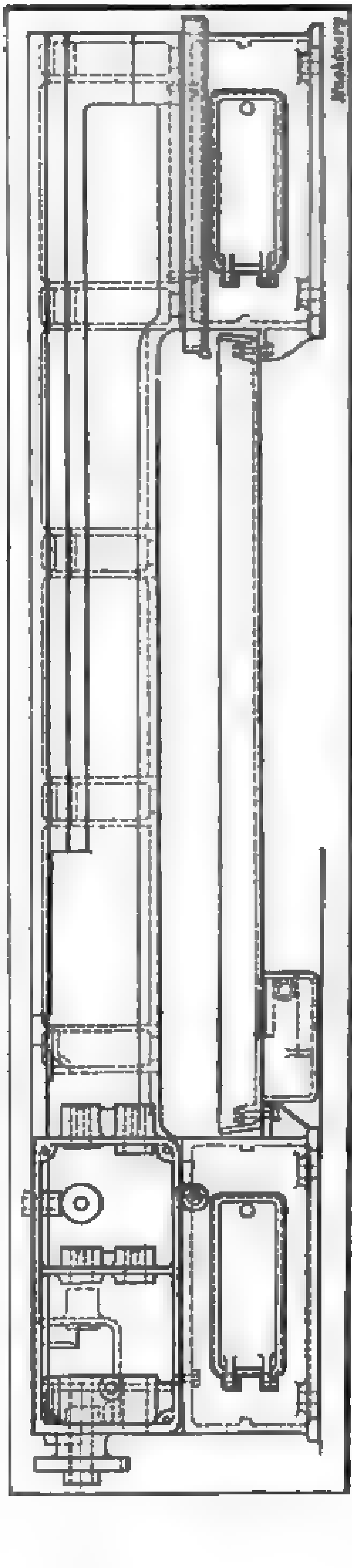


Fig. 55. Bed for [illegible] High-speed Lathe built by Smith & Coventry, Ltd., Manchester, England

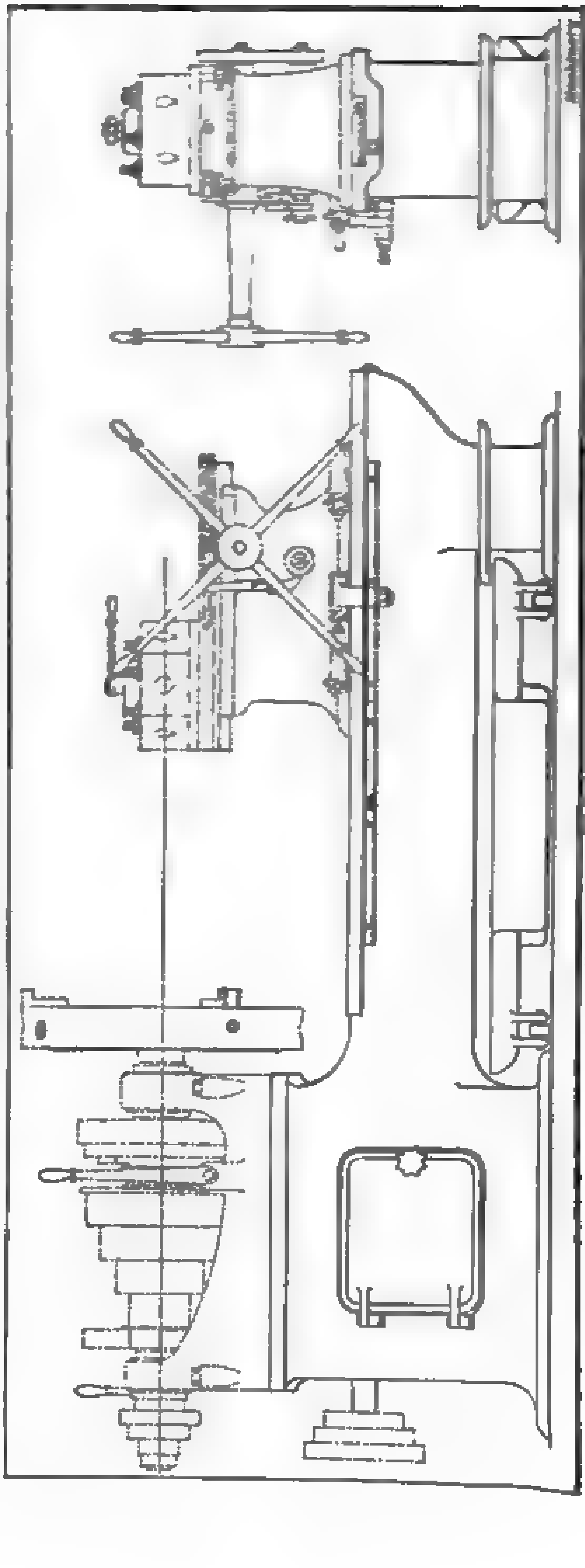


Fig. 56. Type of Bed used for Chucking Lathe

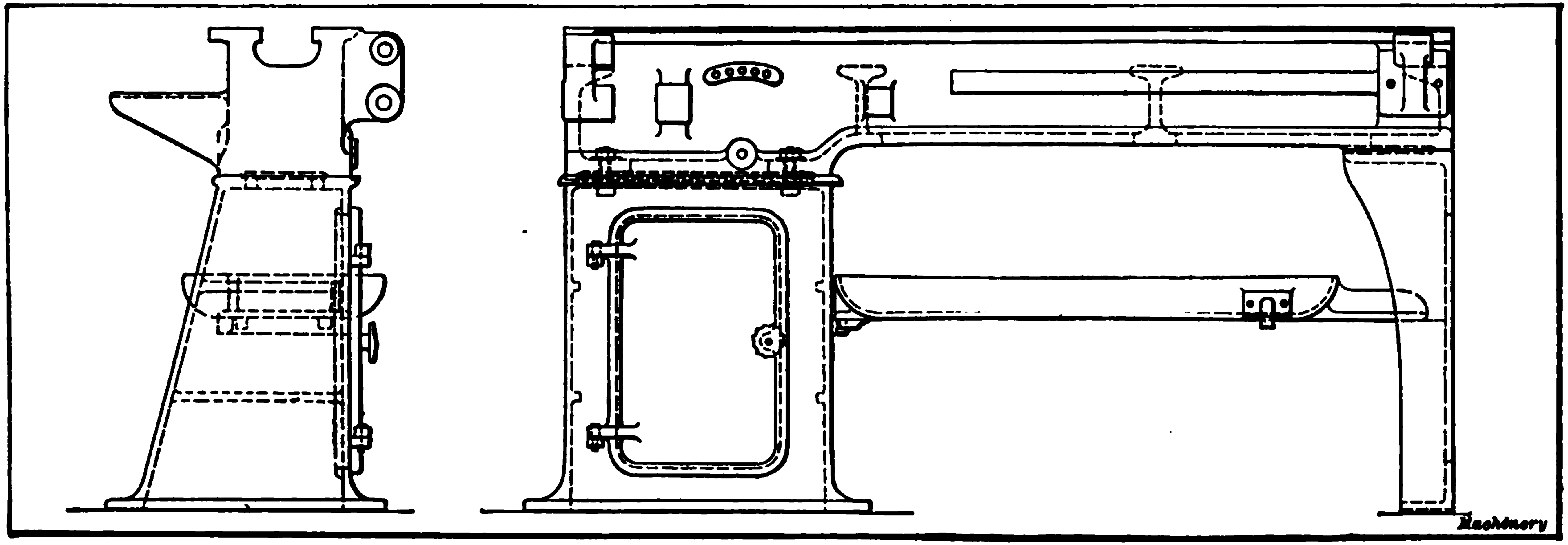


Fig. 67. Bed with Wide Cabinet Standard at One End

supported at this point on the wide cabinet base. An example of a straight bed supported on three equidistant bases is shown in Fig. 68, this being the bed of a Darling & Sellers' lathe, the section of the bed and saddle for which was shown in the previous chapter. It will be noted, from the elevation, how the lower tier or guide rail would support the carriage if a gap were used. A design of bed for a chucking lathe is illustrated in Fig. 66; this is of the box type, with ample support underneath the headstock, and is particularly well adapted for heavy work.

Two designs of beds which embody the same idea, with different proportions, are shown in Figs. 64 and 67, the first being for a small lathe, and the second for a larger one. A cabinet leg is used under the headstock end in each case. For beds of the proportions shown in Fig. 64, it is not generally the practice to use a cabinet base, but regular ribbed legs at both ends are used instead.

The arrangements for lubrication of the cutting tool and

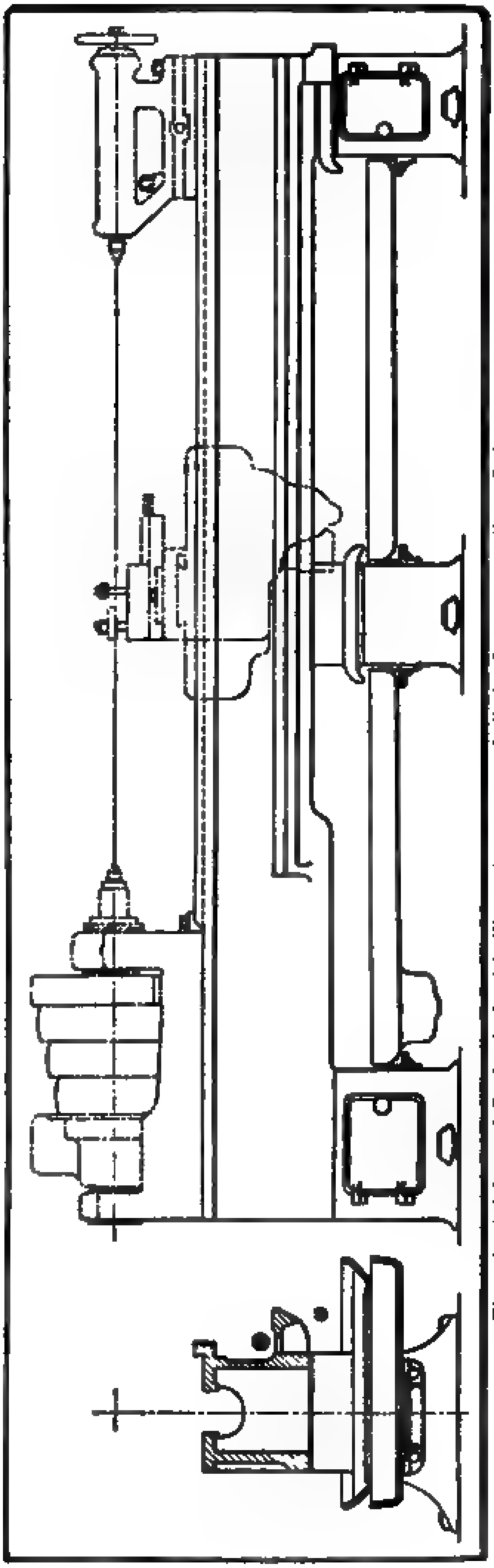


Fig. 68. High-speed Lathe Bed with Three Supports, as built by Darling & Sellers, Ltd., Keighley, England

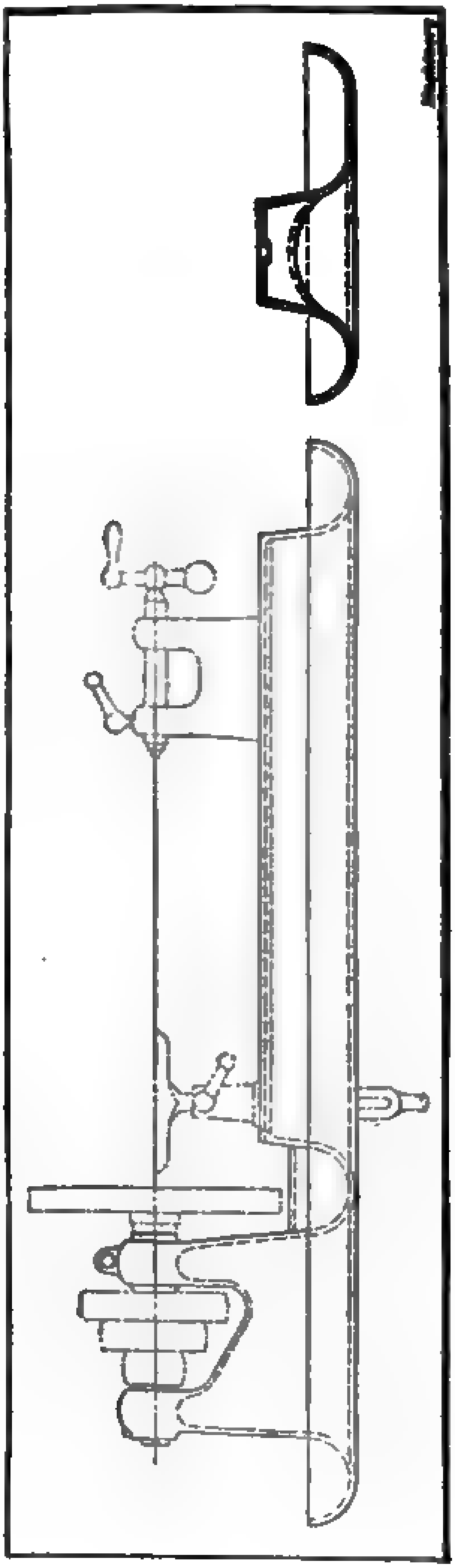


Fig. 69. Bed for Small Lathe with Head and Oil Pan cast Solid with it

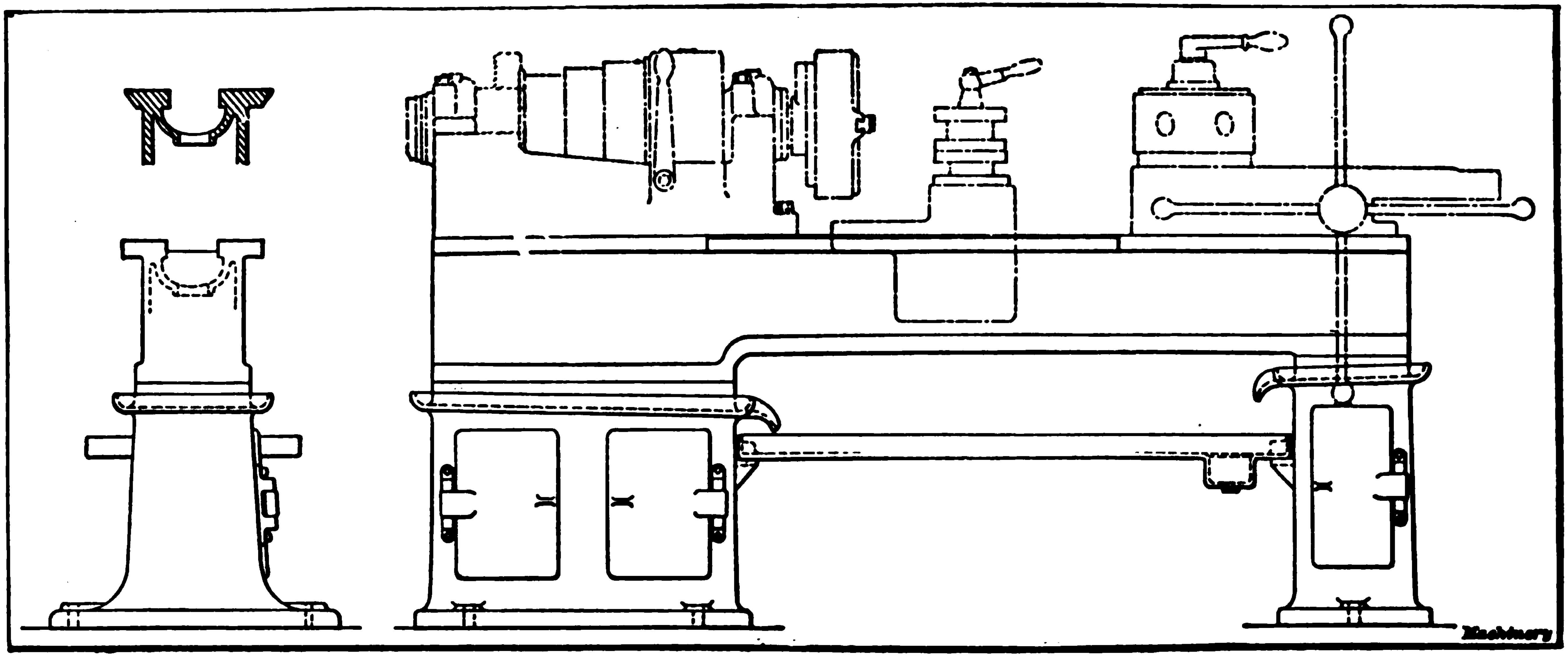


Fig. 70. Bed with Two Cabinet Standards of Unequal Size

work, as mentioned, affect the extent to which the bed is provided with oil-catching devices. The most complete method, short of placing the entire bed in a tray, is that represented in Fig. 70, with each base surrounded with an oil rim, leading into the trough between them. This arrangement does not provide for splashing, unless a sloping guard is fitted in front, or in both front and rear. A step further consists in fitting a single tray large enough to extend around the entire bed. A more elaborate design is illustrated in Fig. 71, in which the tray is of ample capacity. An addition is sometimes made in the shape of sloping guards or oil catchers hung on the rim, not only

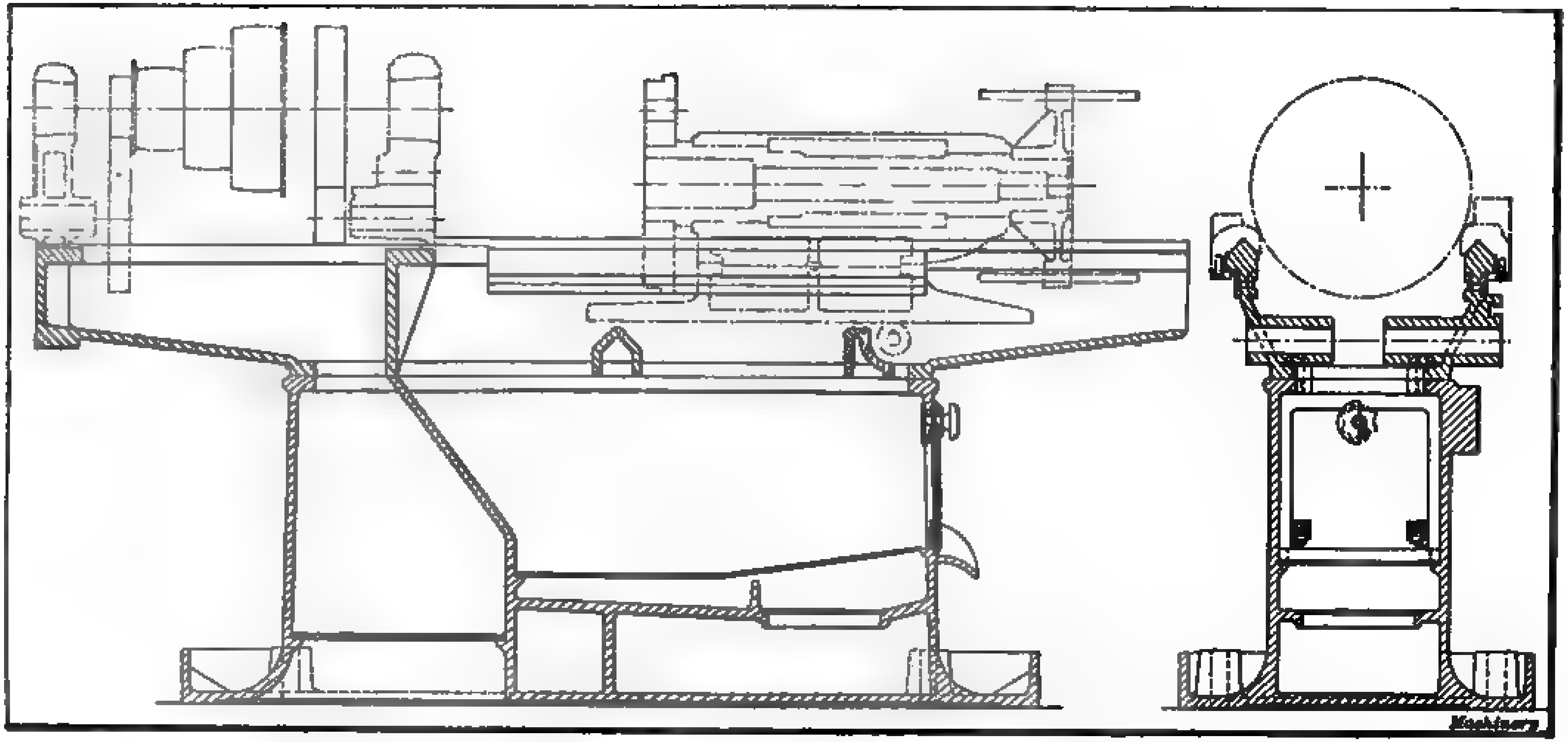


Fig. 72. Bed for Pittler Turret Lathe as built by the Leipziger Werkzeug-maschinenfabrik, Leipzig-Wahren, Germany.

gether. This design is adopted largely in high-speed lathes with all-geared heads, the webbing extending up from the bed to form the lower half of the gear guards. There is then an opportunity for coring out a cavity large enough to receive big cone pulleys or gears, which could not be done if the head were made separately.

A neat design of bed and head for a small lathe is shown in Fig. 69, cast with a large tray around it. Fig. 72 shows the bed used in some of the German Pittler turret lathes which are supported on a single box base arranged as shown with a strainer and trough for the lubricant and a receptacle for tools, etc. The cross-sectional view shows the jointing of the bed on the standard, and the section of the ways, which carry the turret saddle on vees.

Beds for lathes of large size embody the general principles which have been stated, but they are subject to a number of modifications which are not met with in those of medium and small size. Supporting legs are necessarily absent, the under side of the bed resting on its

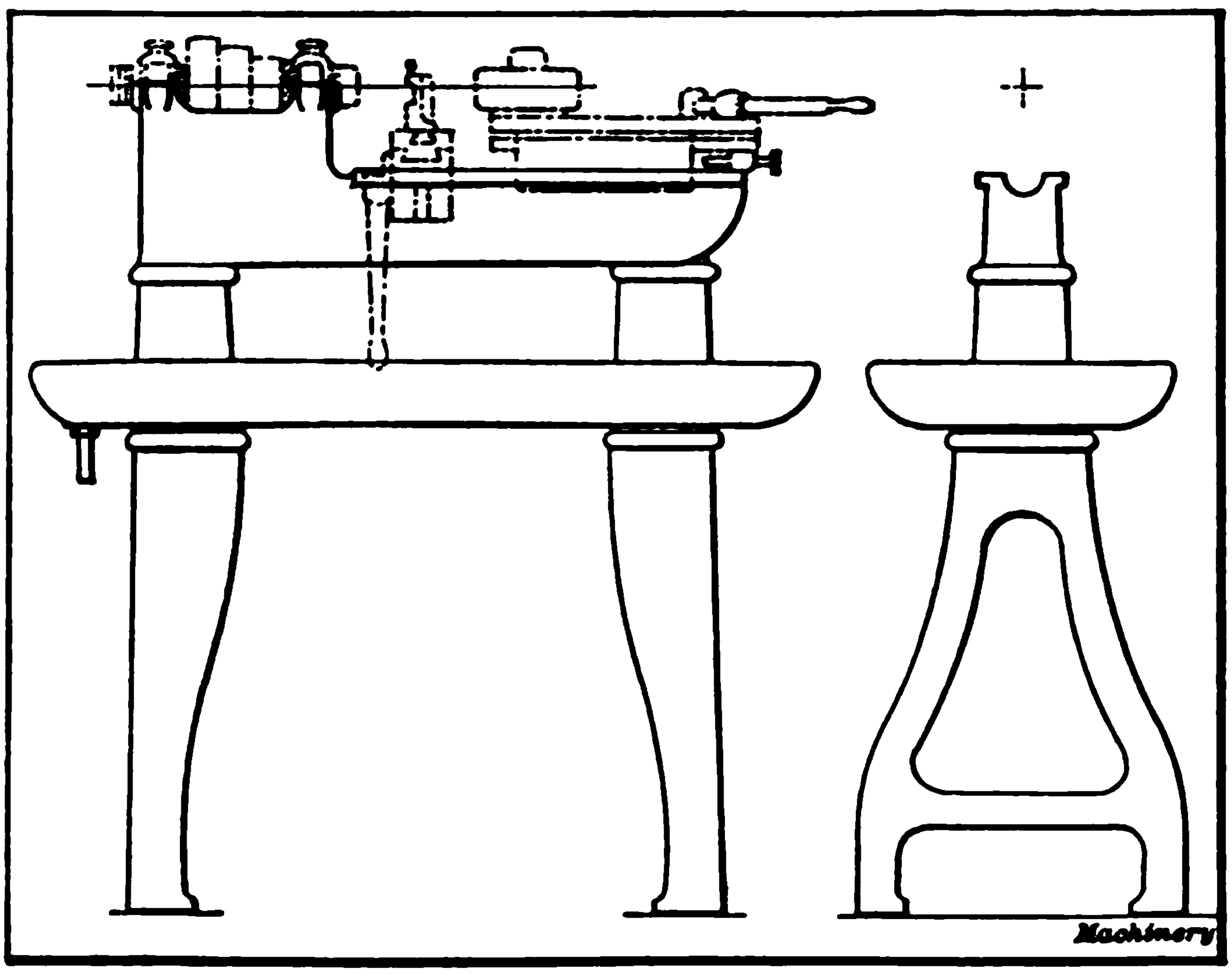


Fig. 73. Turret Lathe Bed with Head cast Solid with it

foundations for its whole length. Joints in the longitudinal direction as well as in the cross direction become necessary on account of convenience in casting, machining or transportation. Gaps or pits are used for lathes required for swinging large diameters, and sometimes the head is independent of the bed, except that it is mounted on the same foundation, that is, the cast-iron bed is not continuous. In some facing lathes the bed does not extend in the longitudinal direction, but comprises merely a support for the slide-rest. The slide movements are obtained only from the rests, and not from the bed. Sometimes the longitudinal extension of the bed from the headstock carries only a tailstock or a boring head, and the rests are supported on wings extending toward front and back.

Fig. 39 illustrates a built-up bed, with curved ribbing underneath, and a slide bed for carrying the tailstock and the saddle. The extension plate at the front carries the saddle of the rest for turning large work.

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CHAPTER I

MACHINE STOPS, TRIPS AND REVERSING MECHANISMS

In recent years, stops, trips and reversing mechanisms have been applied to a vast number of machine tools. The stops employed vary from the simple adjustable stop, tappet or dog, to the mechanisms in which these are combined with cushion devices, means for reversing feed movements, etc.

It may be advisable at the outset to call attention to the difference between a "self-acting" and an "automatic" movement. Many machines which are not wholly automatic contain self acting movements. A slide-rest is self-acting, though the lathe is not automatic, because the movements of the slides have to be thrown in and out by the operator. The greater number of turret lathes are semi-automatic or self-acting, as distinct from the automatic or "full automatic" screw machine. A number of gear-cutters and grinders, in which all the movements proceed without intervention from the attendant, are also in the class with the fully automatic machines. It is in these classes of machines that the highest developments of the mechanisms to be considered are found.

There are two kinds of stops: "Dead" stops are those which positively arrest a movement, and gage a length or diameter in repetitive work; "trip" stops or "trips" throw out a movement, reverse it, or throw it in again. Dead stops alone are not sufficient to check a power feed or self-acting movement, some means must also be provided to throw out the feed. Then a dead stop may or may not be incorporated to form a positive check. In many cases the tools themselves, as in some turret-lathe work, constitute dead stops, and render the provision of additional stops unnecessary. A dead stop is used in hand-operated mechanisms to prevent the operator from moving the slide or other portion further than the predetermined limit, thus guarding against error, and insuring a duplication of dimensions without the need for measurement or gaging. Again, it is often possible to throw out a dead stop temporarily, and go past it for certain purposes, such as inspection, and again throw it in at the same setting as before. A number of dead stops may be located close together, to enable selection to be made at will or in regular rotation, as in the case of a turret one for each tool-hole. Frequently duplex stops are arranged, to enable the choice of two distances for a single slide, one stop being thrown out of the way. Fine adjustment is in some cases provided for a dead stop, so that a very precise setting can be obtained

An important point in the design of dead stops is that of rigidity; a solid abutment should always be used, and any excessive overhang tending to cause springing must be avoided, otherwise
are impossible. In the operation of a hand turret

chine tool there is necessarily a great deal of banging and rough treatment, especially in the hands of a careless operator, and weak and badly-supported stops will cause unsatisfactory work. The binding arrangement for a stop must also be efficient, so that it will not slip and cause a batch of work to be turned out to wrong dimensions. The hardening of contact surfaces is also advisable for preventing wear and bruising that would affect the dimensions of work produced.

The position and method of attachment of a dead stop depends on the class of machine and the design. Where a sliding table has to be stopped, it is in many cases possible to attach the stops or dogs by means of a bolt and T-slot in the edge of the table, this being a very simple method and permitting easy adjustment; or a round rod may

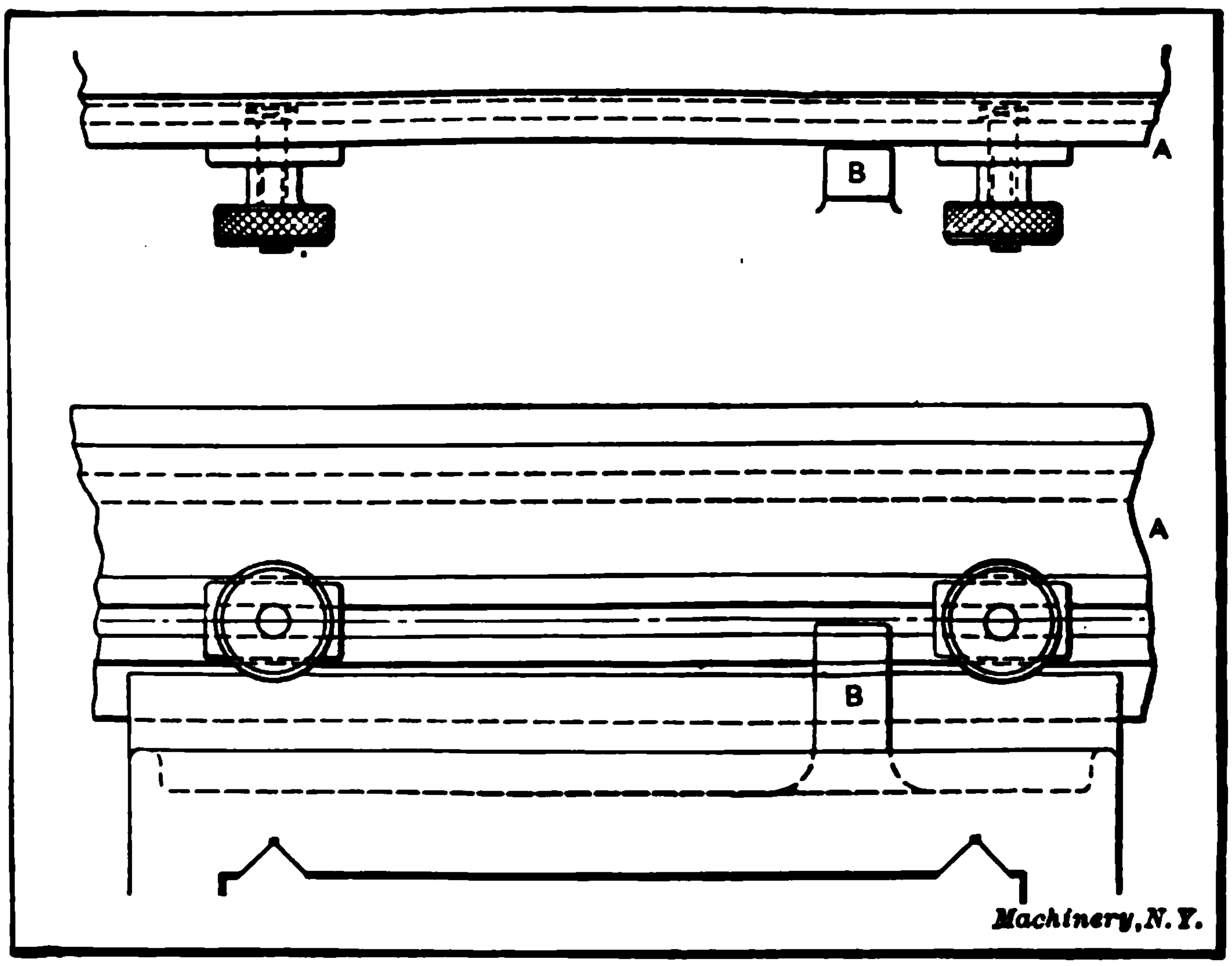


Fig. 1. Dead Stops of a Type used on a Cutter-grinding Machine

be held in bearings on the edge of the table, and adjustable dogs be clamped to the rod by set-screws, or by split ears or lugs. Another method is to have a fixed stop bolted to the table edge, and adjustable dogs attached to a rod in front, these being struck by the stop according to the momevents of the table. A favorite device for short slides, such as the cross-slides of turret lathes, is to attach the stops to a rod or screw passing through a hole in the slide, the faces of the latter coming into contact on each side alternately with the stops. Plain cylindrical parts, if of small diameter, are often controlled by a collar or lug, clamped to them by means of a set-screw, and arranged to encounter the face of the bearing through which the part moves.

It is evidently impossible to show all the different kinds of stops which are in use on various machine tools, but the following selection of typical examples embodies the principles involved in the design of all stops. Slight modifications are made in different machines.

In Fig. 1 is shown the simplest possible kind of dead stop applied to the table of a cutter grinding machine. We have here a T-slot in the edge of the moving table *A*, receiving the heads of the bolts which clamp the two stop-plates through the medium of knurled nuts. The plates strike tne block *B* on the transverse table

Fig. 2 shows a modification of the same principle In this case the sliding head *A* of a vertical milling machine is to be stopped in one direction only—the downward—and a projection stands out from the slide *A* to encounter the end of the stop-screw in the block *B*, which is clamped in a T-slot on the fixed head. After adjusting *B* approximately in position up or down in the slot, by the lever, the final adjustment is made by the knurled-head screw, which is finally locked by its nut. The screw does not, however, provide a precise means of setting to any exact measurement. In some cases, therefore, such a stop-screw has a micrometer adjustment, Fig 3. The head of the screw is graduated, so that the screw can be adjusted by a known amount—a manifest advantage in fine work. The body of the stop is split, thus providing positive means for binding the stop-screw.

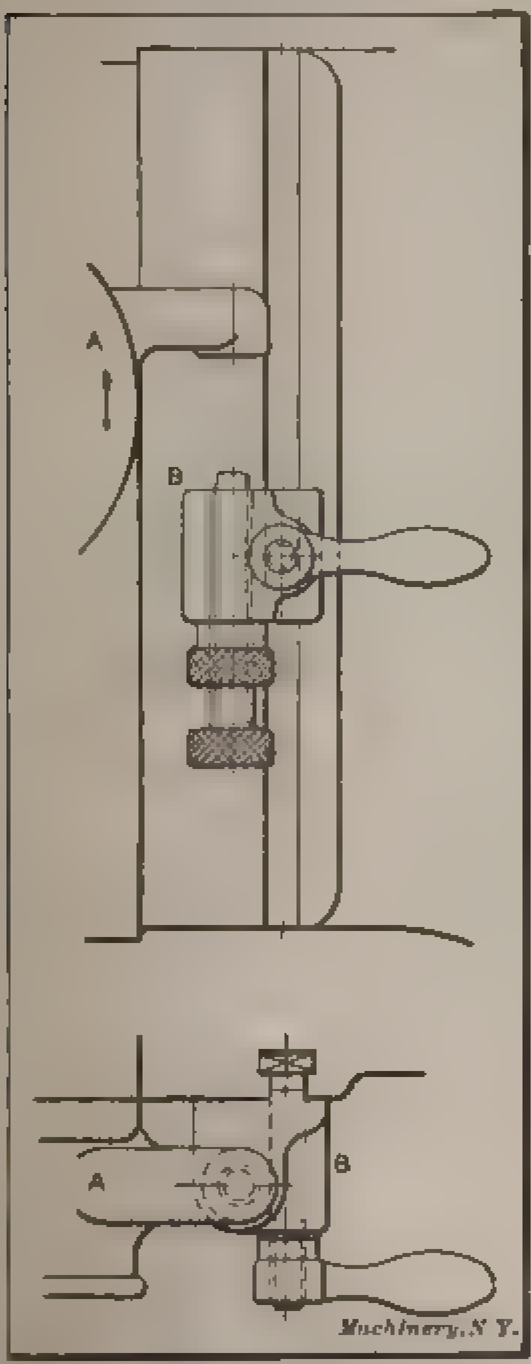


Fig. 2. Dead Stop used on a Vertical Milling Machine

An illustration of the stop-screw or rod passing through a hole in the moving slide is shown in Fig. 4. The example shown is that of a cross-slide of a turret lathe. The stop-screw in this case also serves the purpose of moving the rest along through the medium of the hand-wheel and the miter gears; frequently, however, a separate plain rod is used, parallel with the screw, and carrying split clamped dogs instead of the double lock-nuts, shown in Fig. 4 Another example of the use of double nuts is shown in Fig 7, illustrating the rear end of a cross-slide for a turret lathe. The stop-screw is tapped into the fixed slide, and passes through an extension on the moving slide T[illegible] serves as a stop for both front and back tools Ir[illegible]g. 18, two screws are used locked with nuts, the t[illegible] struck by a pin screwed

into the moving slide. The advantage of both these designs of stops is that they are perfectly central, and are therefore better than those classes of stops which are set at the side of the moving slide.

The combination of two stops, to provide the choice of two lengths, is common. A case of this kind is shown in Fig. 5, showing the rear end of a turret slide. The main screw *A*, with a locking nut, abuts

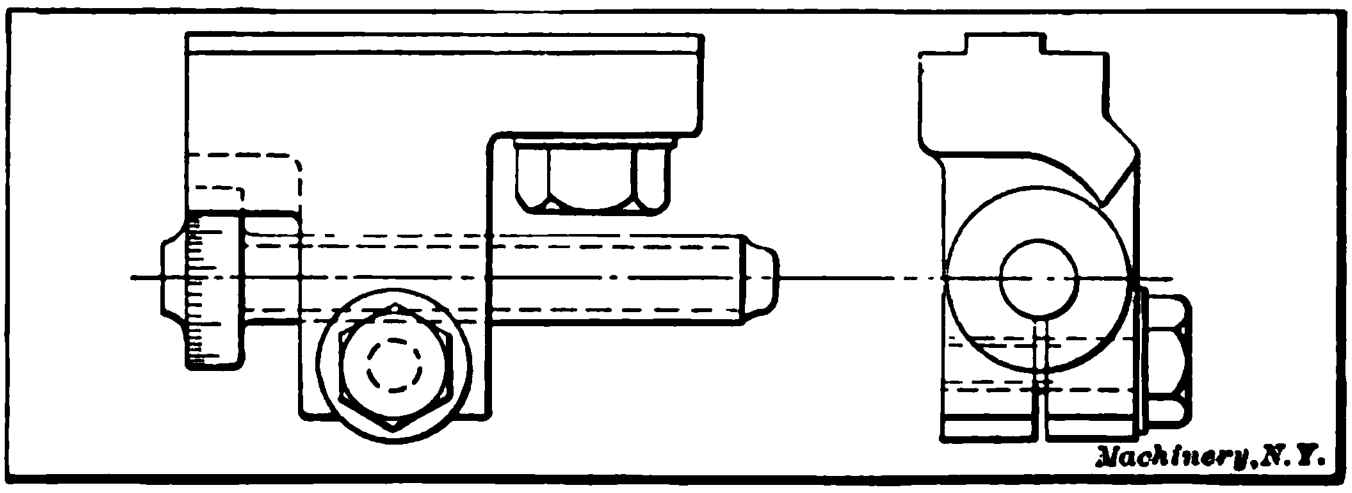


Fig. 3. Stop-screw with Micrometer Adjustment

against the back of the saddle or base, and forms one dead stop. An adjustable block *B*, bolted to the edge of the slide, carries a pivoted dog *C*, which when dropped down into the position indicated in the view to the left, strikes against a facing on the back of the base. A flat spring *D*, screwed to *B*, presses against the tail of *C* and maintains it

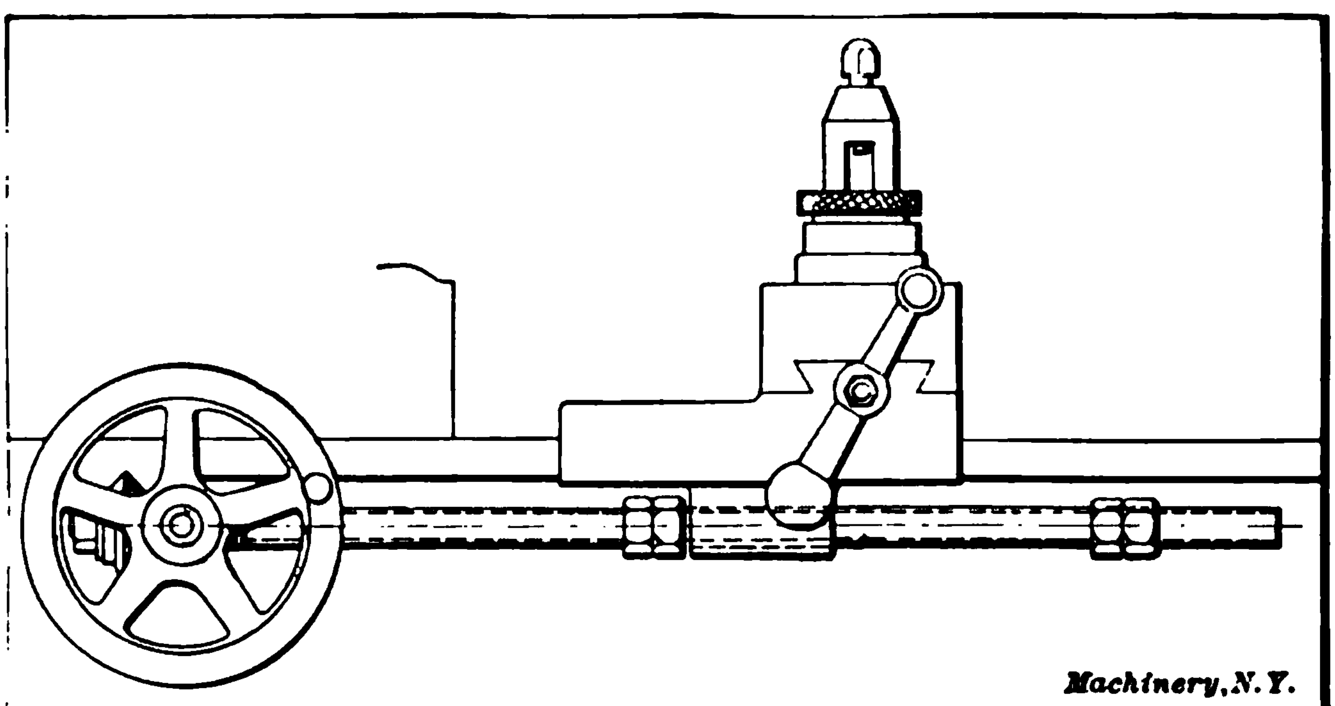


Fig. 4. Stop-rod passing through a Hole in a Turret Lathe Cross-slide

in position. If *C* is not required, it is swung up into the horizontal position, where the flat spring also retains it.

A simple kind of stop for round spindles is shown in Fig. 6. The example shown is used on a sensitive drill press, and consists only of a split collar, which arrests the downward travel of the spindle by striking against the top bearing.

One of the most valuable principles in stop construction is that of the rotary disk carrying several stops, any one of which may be brought into action, either in a selective manner—that is, according to t wish of the operator—or in automatic fashion—one or more stops be made to act only for a particular tool or set of tools. In this way co pactness is secured, and the stops are in full sight and easily accessi

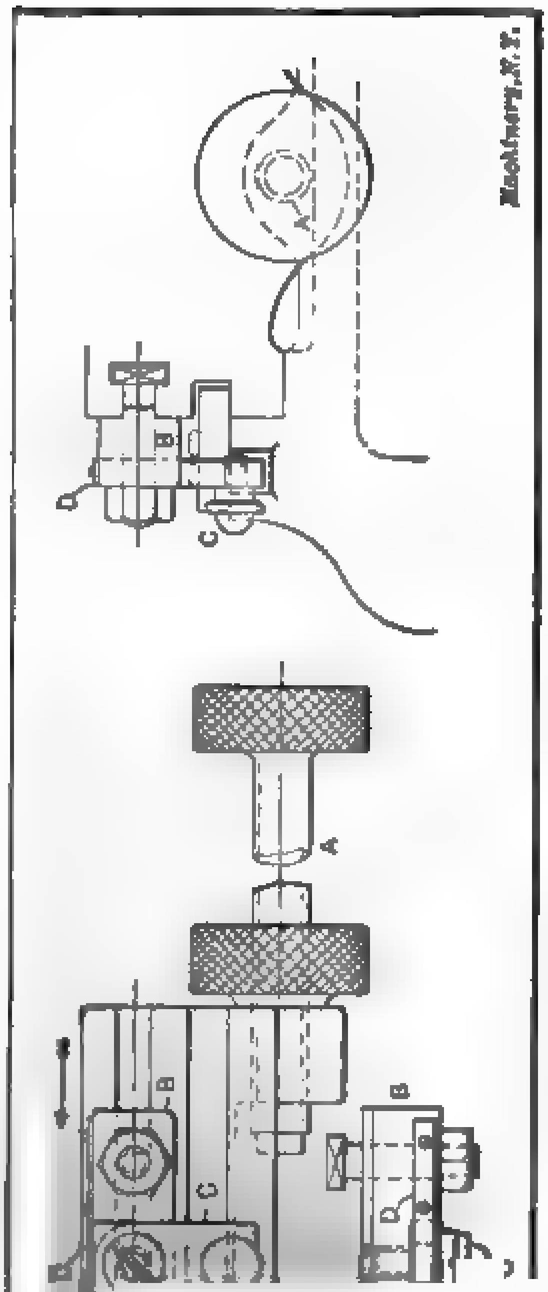


Fig. 5. Double Stops used on Turret Lathe, making it possible to obtain Two Lengths without the Necessity of readjusting the Stop-screw

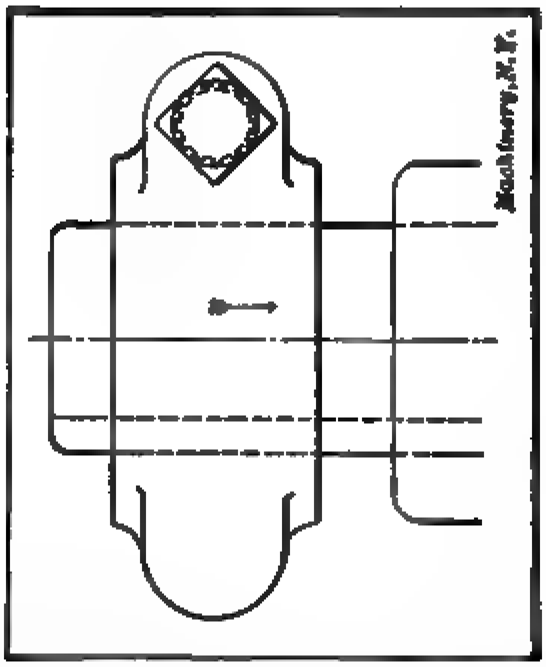


Fig. 6. Split Stop Collar used on Drill-press Spindle

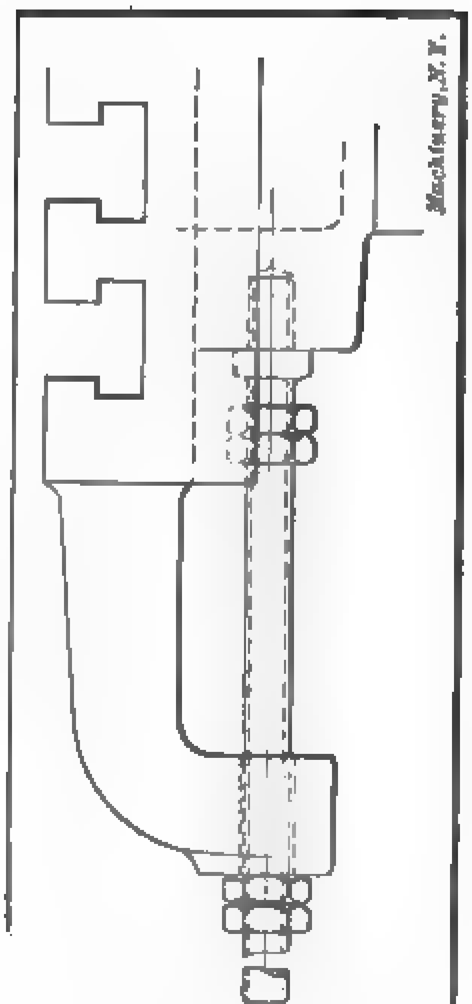


Fig. 7. Efficient Type of Stop-rod for Turret Lathe Cross-slide

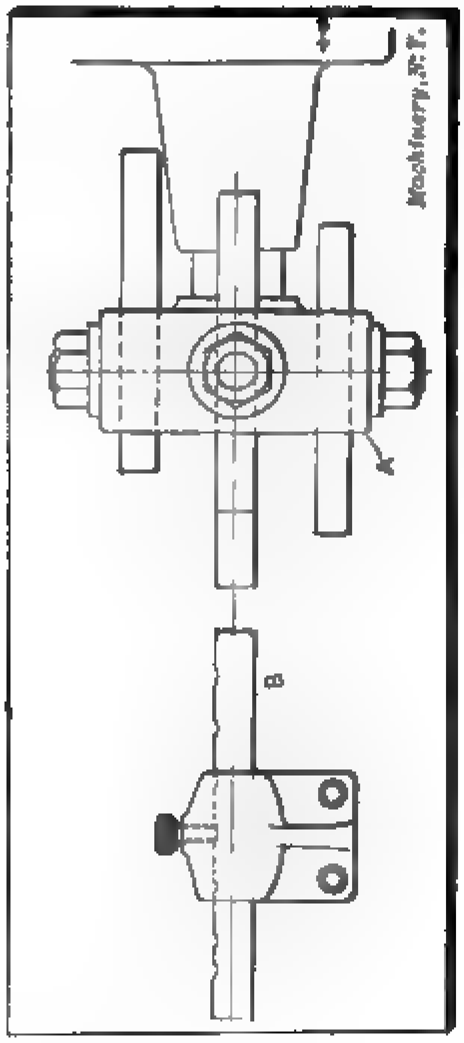


Fig. 8. Rotating Dead Stops used on a Turret Lathe Cross-slide

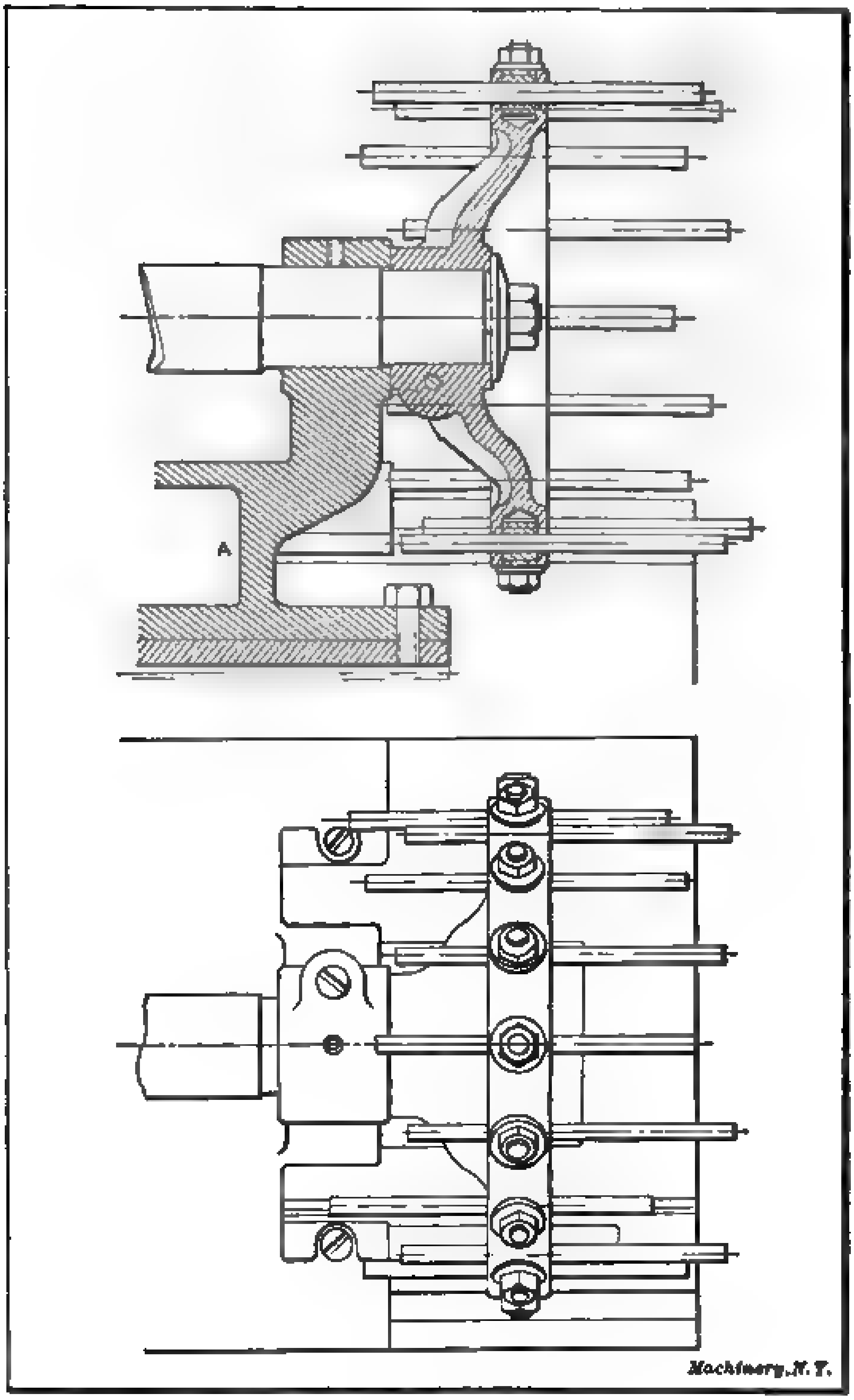


Fig. 9. Dead Stops used on a Turret Lathe of German Make

which was not the case with some of the older designs of multiple stops, such as, for example, a set of flat bars laid side by side and used for turret stops. Fig. 8 illustrates a rotating type of stop, adopted for the cross-slide saddle of the turret lathe, there being one stop-rod for each tool on the cross-slide turret. The head *A* is mounted on the end of a shaft that is rotated simultaneously with the turret, and each of the stop-rods is adjusted independently and secured with a nut, the rod passing through the body of the bolt. Each rod in turn abuts

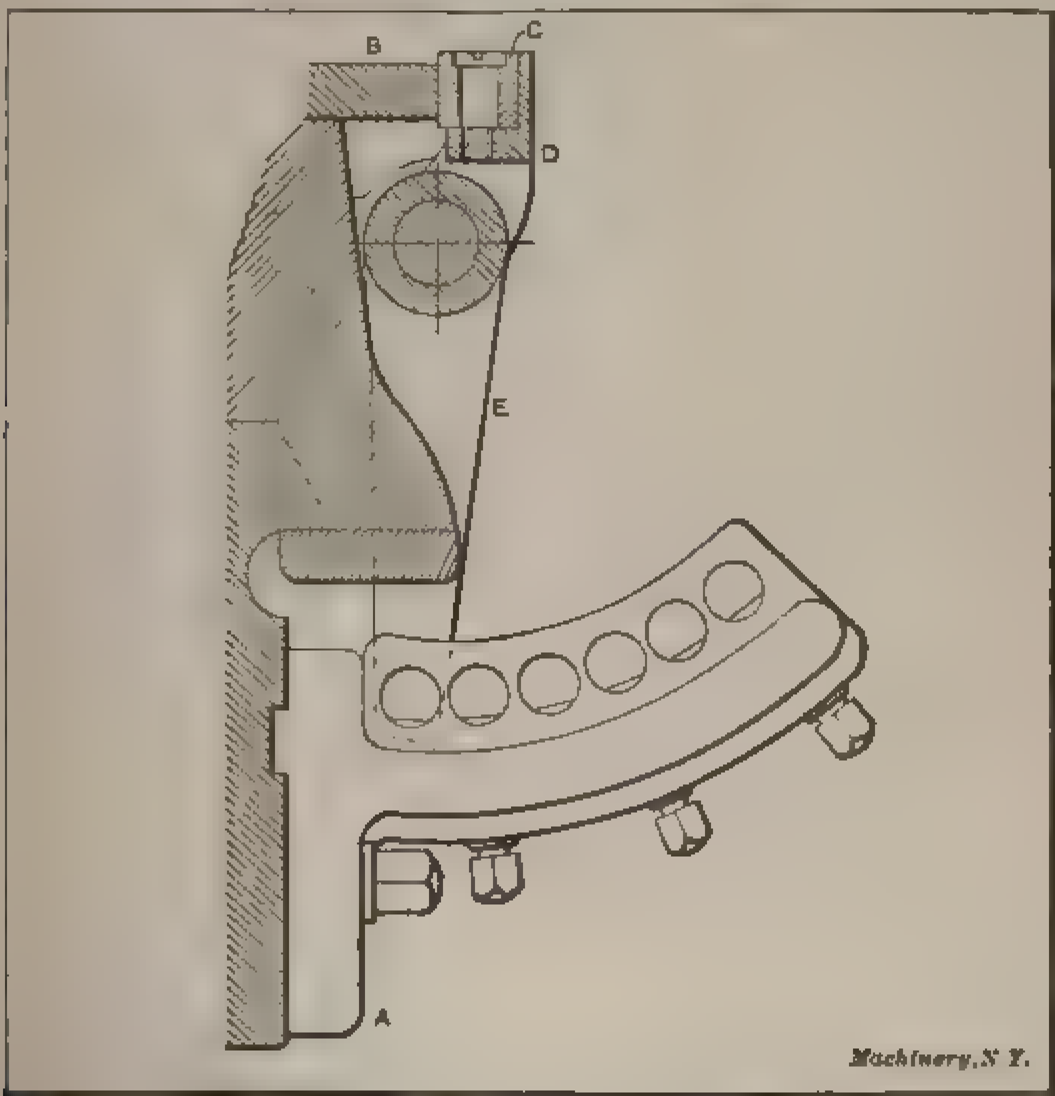


Fig. 10. Turret Lathe Stops used on the Pratt & Whitney Turret Lathes

against the bar *B*, held in a bracket bolted to the front of the lathe bed. The adjustment of this bar is effected by loosening the set-screw and sliding it through the bracket; on tightening the set-screw, it bears down on a flat milled on the bar, and forms a positive check to slipping.

Another application is shown in Fig. 9. This arrangement is applied to the rear end of the Pittler turrets, which are mounted on a horizontal axis. There are sixteen holes in the turret for tools, and a stop is provided for each hole. All the rods are held in the rim of a disk secured to the rear end of the spindle, on the other end of which the tool disk or turret is secured. The turret slide *A* travels, bringing one stop-rod at a time against the fixed bed.

An arrangement of multiple "selected" by a radial action,

though not set in a circle, is used in the Pratt & Whitney turret lathes. Each stop-rod is held in an adjustable bracket *A*, Fig. 10, bolted to the front side of the bed, set-screws being used for clamping; three of these only are visible in the view. As the turret rotates, a cam *B*, cut on

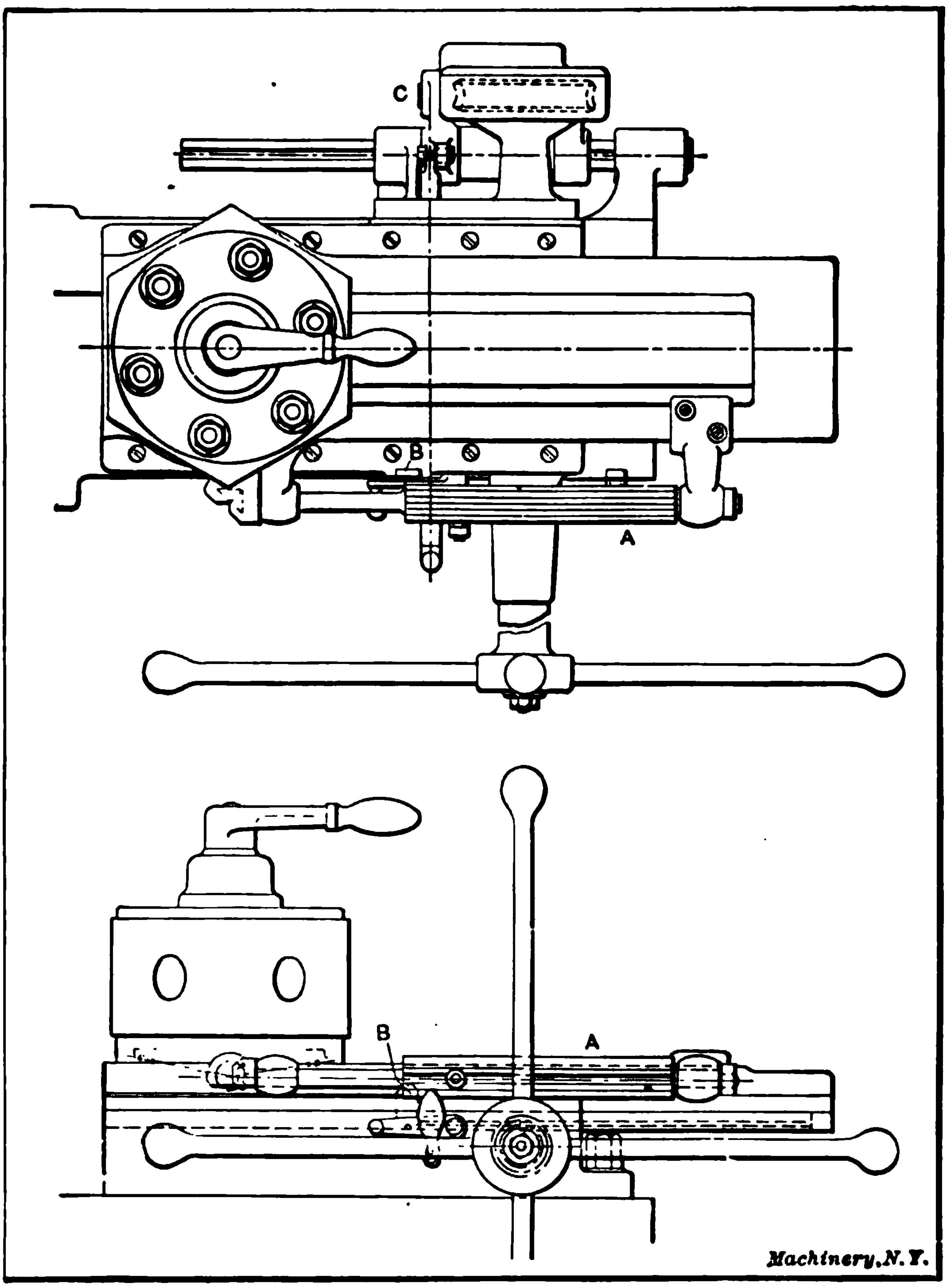


Fig. 11. Rotating Stop-bar used on Turret Lathe

its base, operates a roller *C* mounted on a pivoted lever *D*, and thus brings the flat end of another lever *E*, which is secured to the shaft of *D*, into line with one or another of the stop-rods, corresponding to the position of the tool-holes in the turret. The lever *E* is backed up by a lug projecting from the turret slide (not shown), taking the thrust, and eliminating spring.

A type of rotating stop which has been extensively adopted by turret lathe manufacturers during recent years is illustrated in Fig. 11. The

principle is that of fitting a rotating slotted bar *A* somewhere in front of the turret slide, and gearing it up to the turret to turn in unison with the latter, so that a new face of the bar will be presented for each turret face presented to the work. T-slots in the bar provide for the attachment of stop-blocks or nuts, any number of which may be used on one face. As the turret slide travels along, these nuts come against either a trip lever or a dead stop which lies in their path, and so throw out the feed, and generally also act as dead stops. In the illustration, the nuts which happen to be on the face nearest the turret are touched by the bar *B*, and, by forcing this down, operate a rod that passes through the base, thus dropping the worm-box *C* and stopping the feed.

On the Alfred Herbert hexagon turret lathes a refinement of this type of stop is introduced for the purpose of obtaining the very finest limits in regard to length, by enabling uniform pressure to be put on the stops,

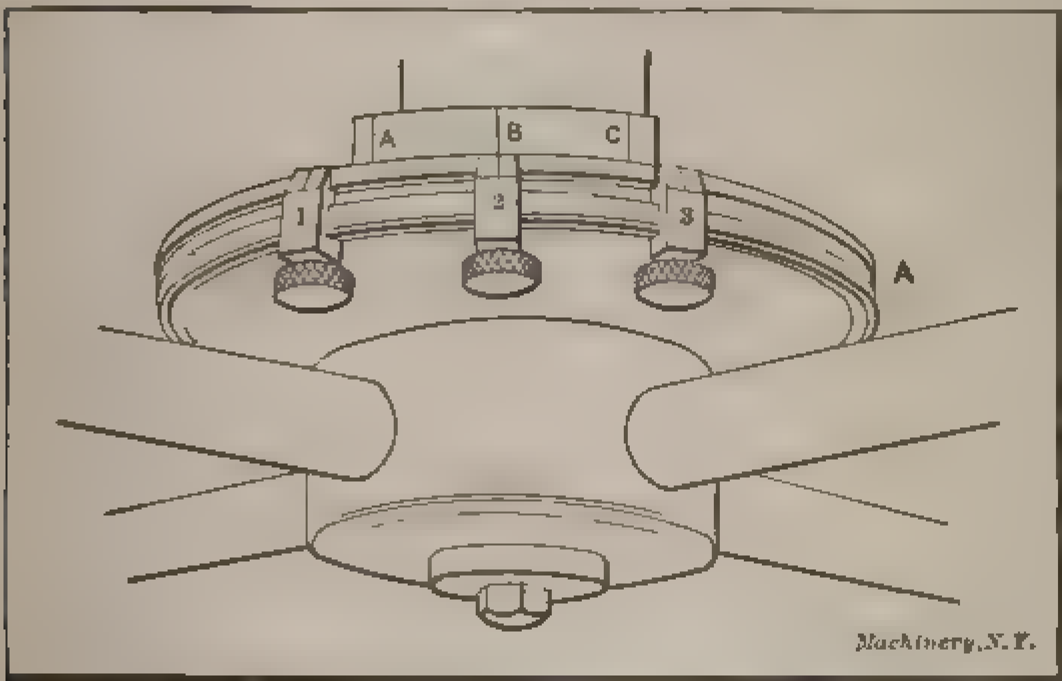


Fig. 12. Enlarged Detail of the Indicator of the Device shown in Fig. 13

independent of changes in the pressure on the cutting tools as they become dull. Fig. 13 shows the appearance of the saddle with the hexagon stop-rod in front, and the pilot handle or spider. In front of the latter is a disk *A*, rotating with the shaft, and carrying three adjustable dogs (see the detailed view, Fig 12) with index lines upon them. The saddle has a fixed sector with three lines corresponding with those on the dogs. After the feed has been tripped by the contact of one of the stops on the bar with the end of the vertical plunger seen in Fig. 13, the saddle can be moved a short distance by hand up to a dead stop. When the saddle is hard up against this stop, one of the dogs on the disk is set to come opposite one of the three index lines on the sector. The dog thus forms an accurate means of measuring the pressure on the dead stop If more than one length is required the two other dogs may be brought into use.

The combined trip and dead stop is found in other ... nes besides turret lathes. Fig 14 represents the front ... table,

with a trip dog *A* which presses down the plunger *B*, and through a pair of levers throws out the feed. The stops *C* are set to abut against the block which receives *B*, and thus act as dead stops, positively arresting the table, so that exact lengths can be milled. If the milling cutter simply has to clear over the ends of the work, the dead stops need not be set, but if the travel has to be stopped at definite positions, they are brought into employment.

When a feed has to be tripped, the actual medium by which it is thrown out depends on circumstances; it may be either through shifting belts, by sliding clutches—toothed or friction—or through a drop-worm. The difficulty with toothed clutches is that of insuring the re-engagement of the teeth. They are reliable enough, when hand-

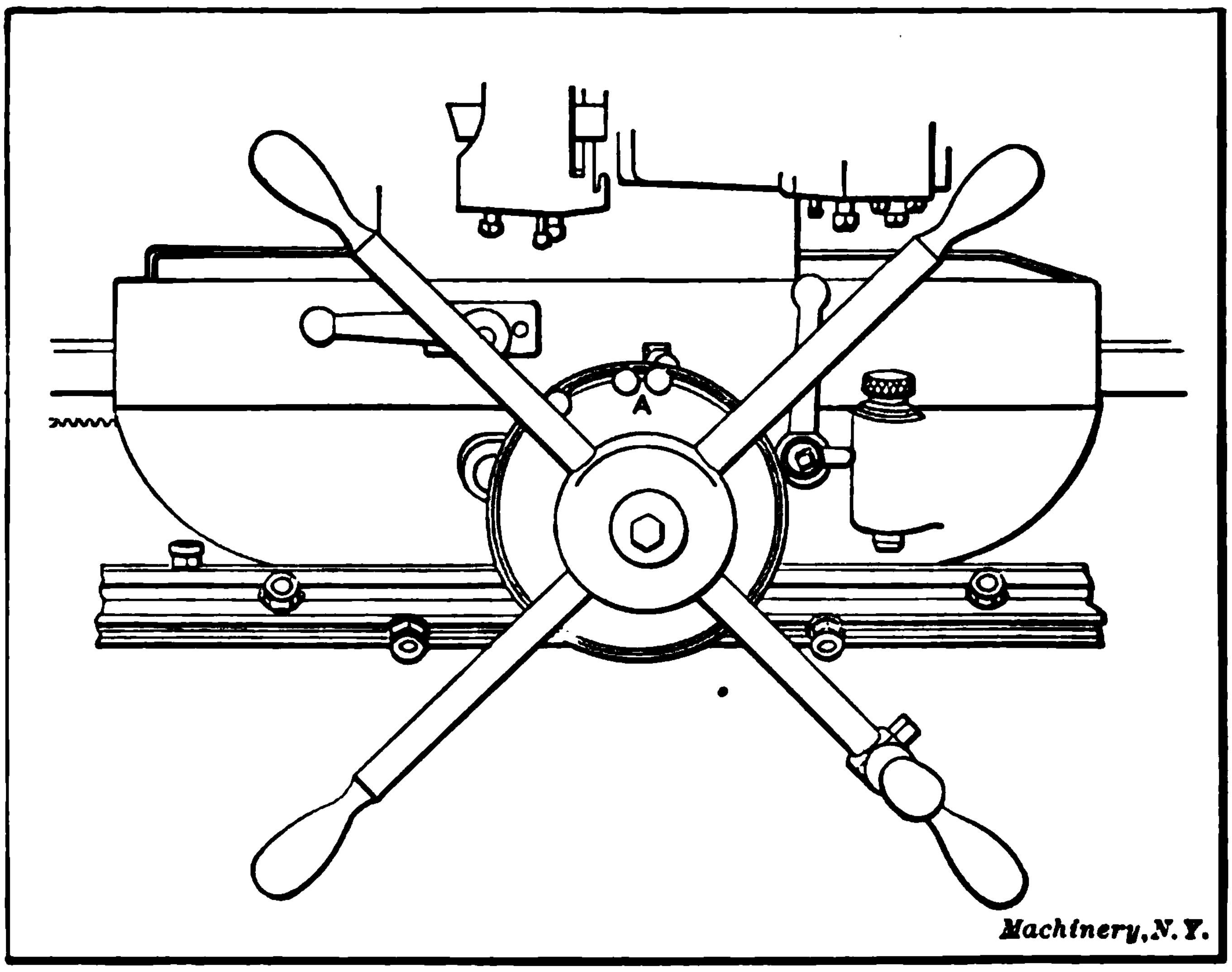


Fig. 13. Rotating Stop-bar and Accurate Indicator used on the Alfred Herbert Hexagon Turret Lathe

operated, but may fail when an attempt is made to render the mechanism self-acting, unless the clutches are actuated by springs or a lever. To render the action absolutely precise, an element must be included to cause both the release and the engagement to take place at an instant. A spring plunger is the device often adopted. A spring is compressed by the movement of the striking lever, which at the same time releases a trigger or catch, setting the spring free to push the clutch into engagement. This method is obviously capable of various applications. The springs may be actuated by a lever or by cams or by other means. A latch or latches lock the mechanism, rendering it impossible to throw any other movement in until they are released. This feature is worked out in various ways and is embodied in several gear-cutting machines to prevent interference between the indexing and cutting operations.

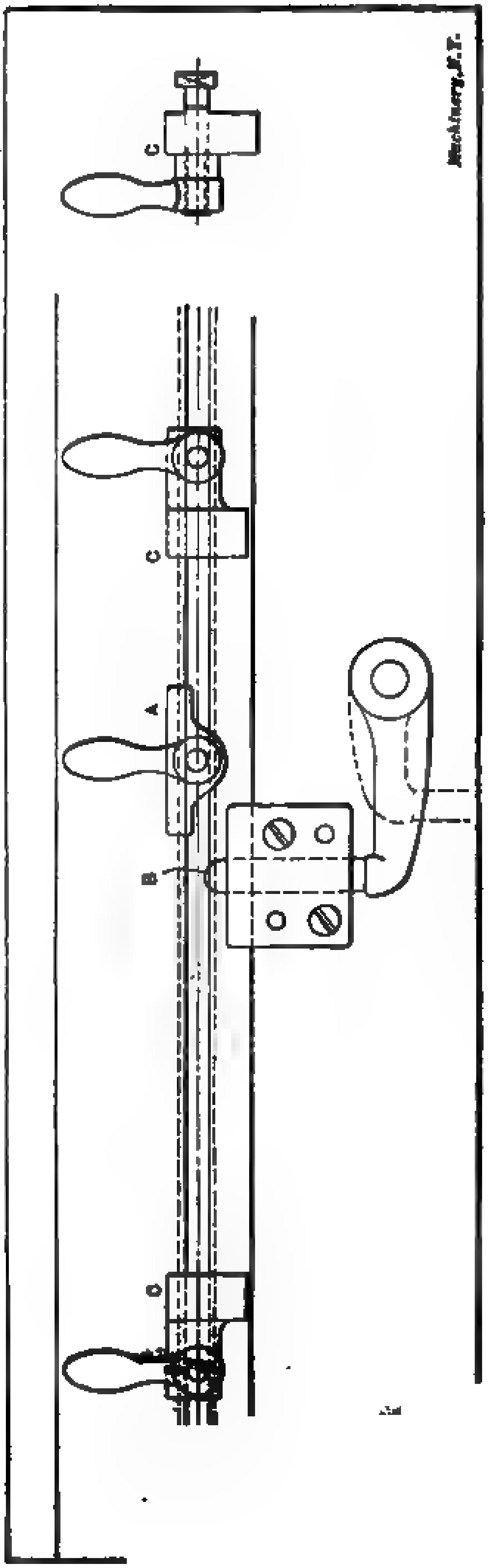


Fig. 14. Combined Trip and Dead Stops for Milling Machine Table

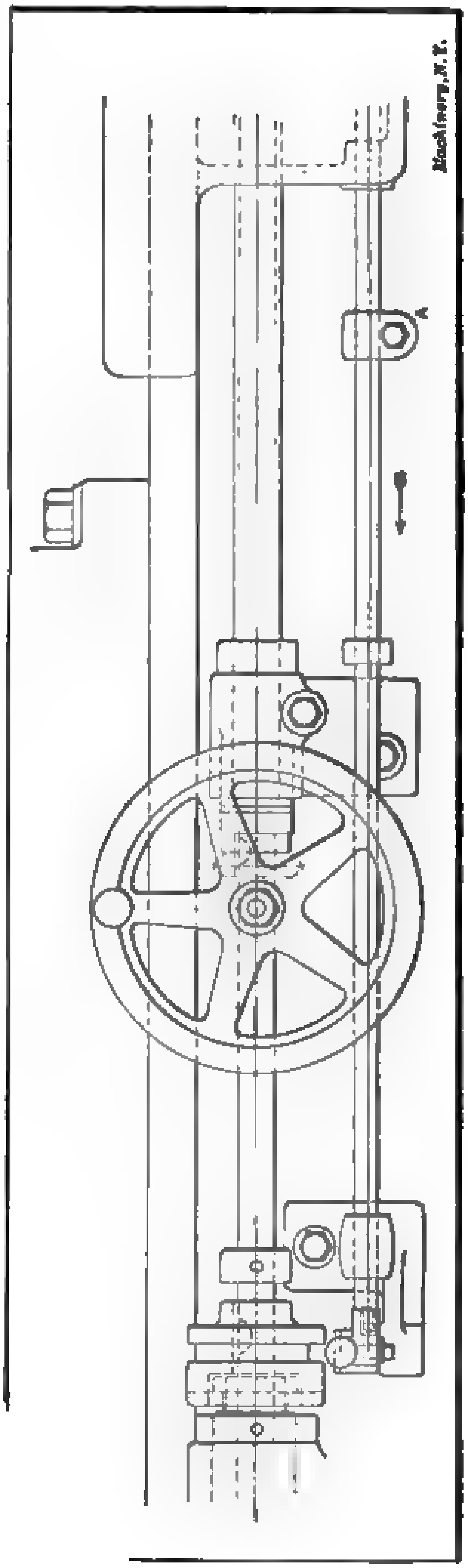


Fig. 15. Trip for Turret Lathe Cross-slide

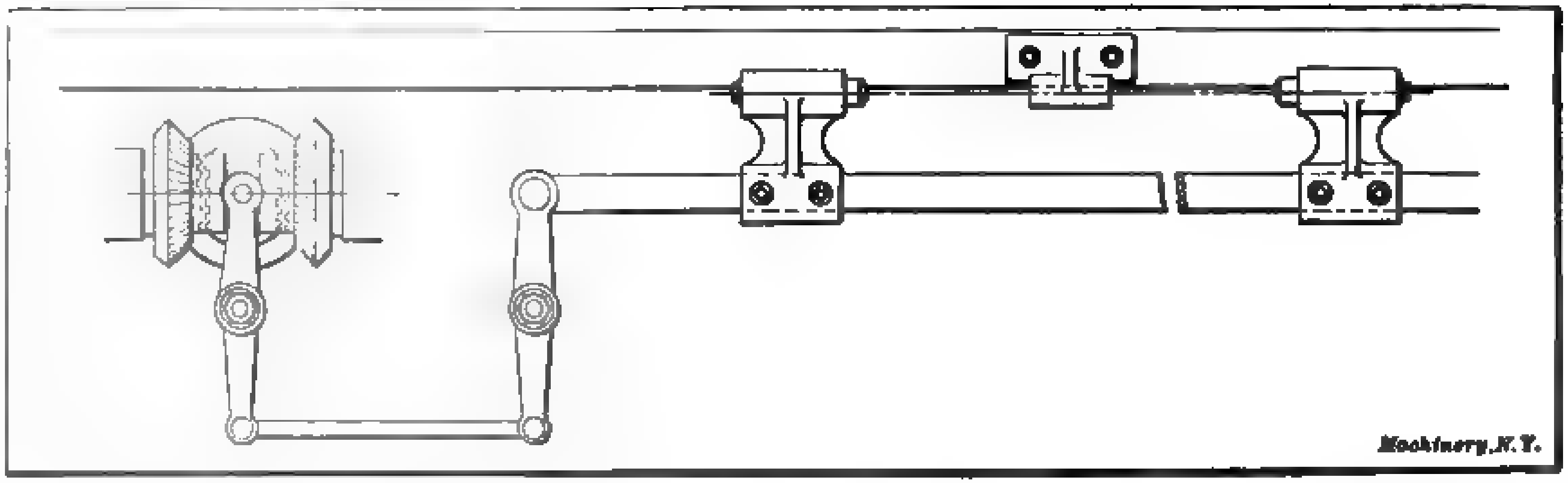


Fig. 16. Double Trip and Reversing Clutch for Grinding Machine

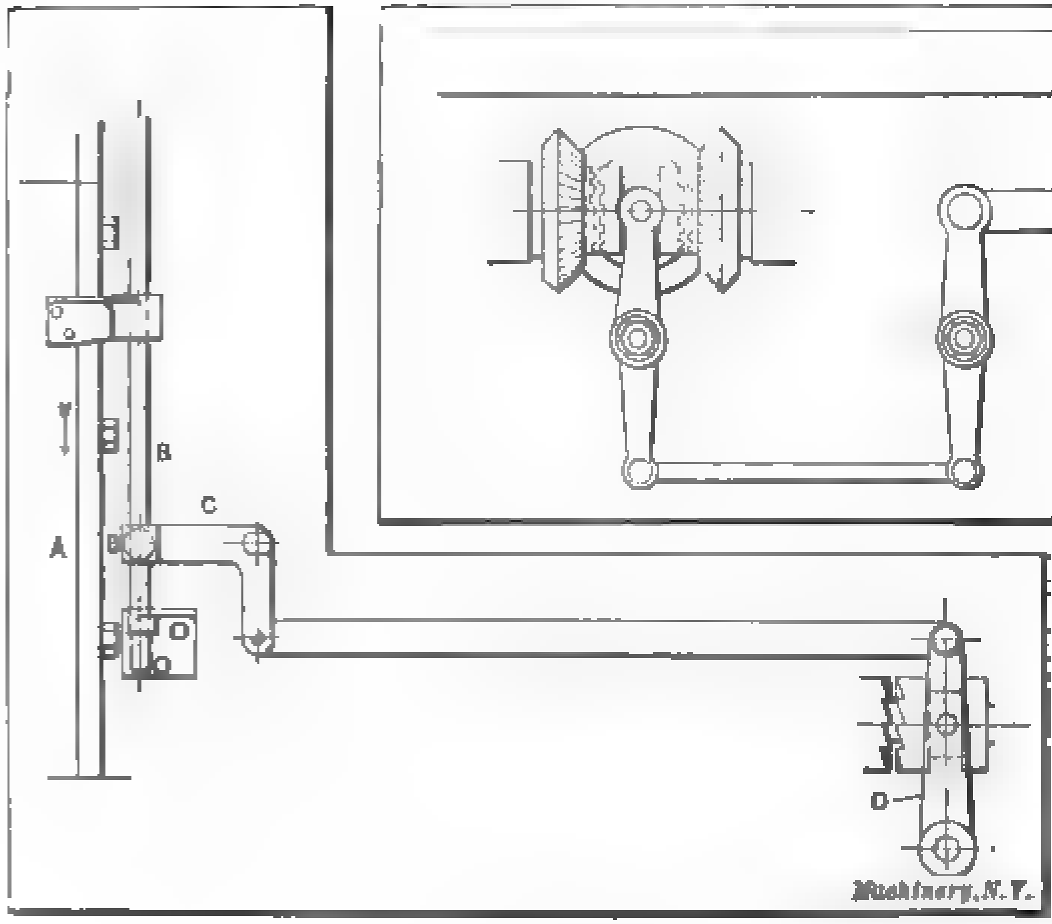


Fig. 17. Example of Single Trip without Reversal

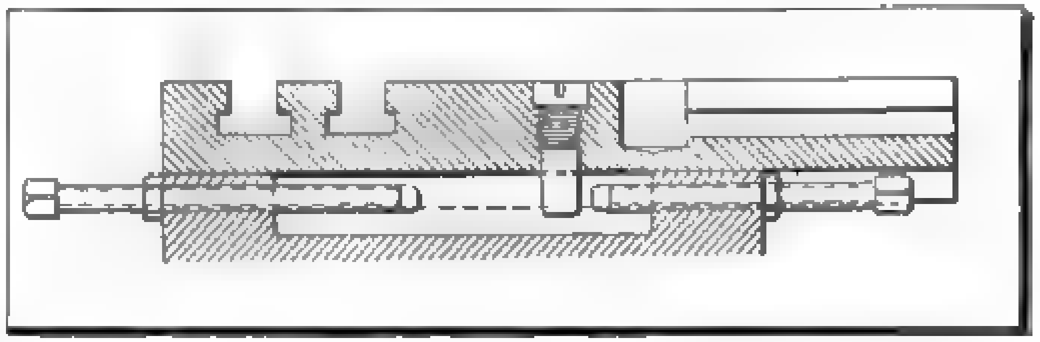


Fig. 18. Double Dead Stops

Two types of simple trips, operating clutches which must be reengaged by hand, are shown in Figs. 15 and 17. The first is for a turret lathe cross-slide, the second for a gear-cutting machine. In Fig. 15 the saddle strikes the clamp-collar *A* on the stop-rod, moving the latter to the left, and actuating the lever which throws out the toothed clutch, stopping the feed to the saddle. In Fig. 17 the function is similar, in that the downward movement of the slide *A* is stopped; a bracket bolted to this embraces the rod *B* on the fixed part of the machine, and strikes the lever *C*

which actuates lever *D* through a link, thus throwing out the clutch, and stopping the feed.

A double trip and reversing mechanism for a large grinding machine is shown in Fig. 16. In this arrangement the dog is bolted to the edge of the moving table, and strikes against adjustable dogs on the flat striking bar, which is connected by levers to the toothed clutch. In this design the table feeds and reverses so long as the driving mechanism is running. This brings us to the question of locking, that is retaining a clutch or other gear in mesh as long as it has to drive. Without some means of locking, there is nothing to prevent the

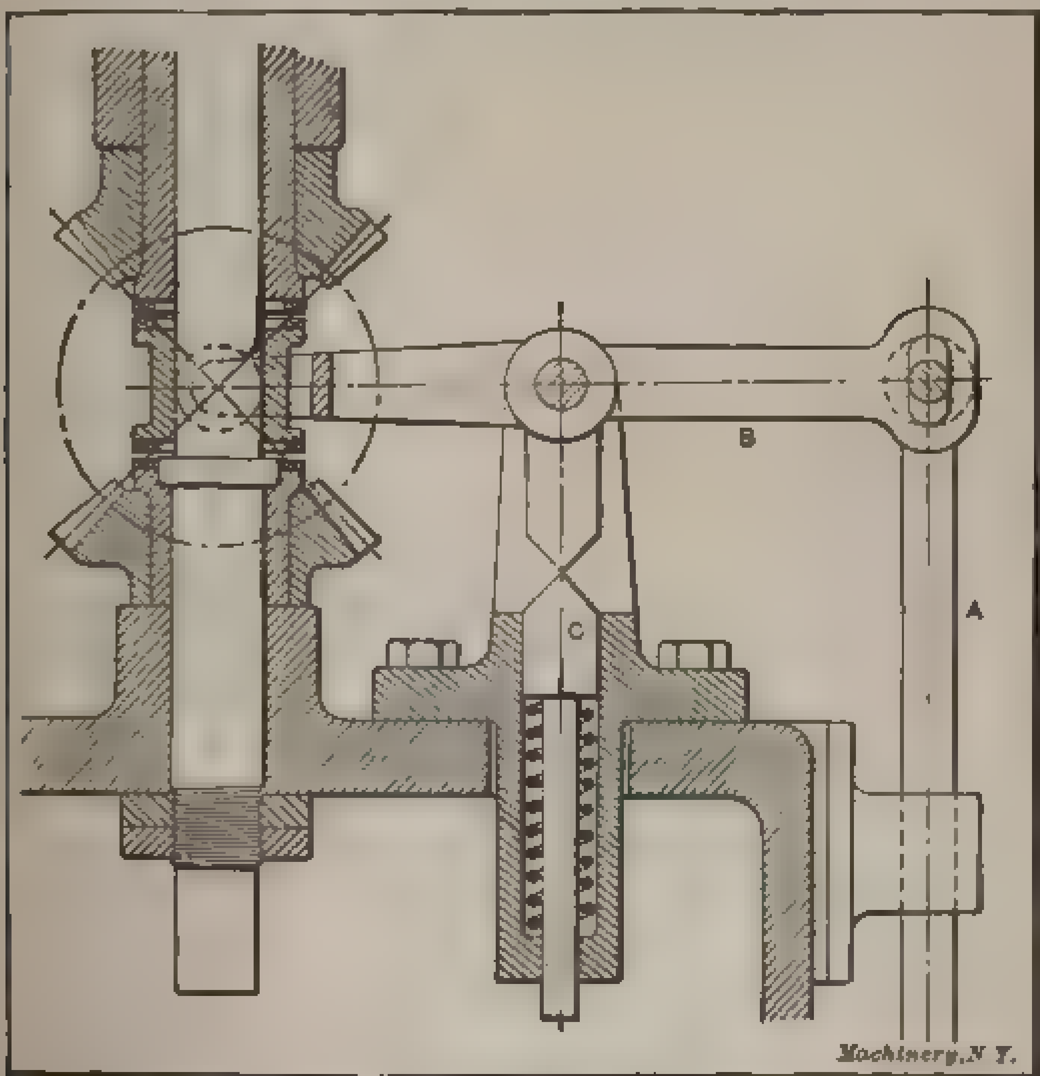


Fig. 19. Method of Locking Clutch by Spring Plunger

clutch from disengaging under the effects of vibration. The simplest and most common method is to fit a spring plunger with a pointed end, or with a roller, which slips down along a beveled end on one of the levers, or into recesses, there being many ways of accomplishing the desired result. Fig. 19 shows the principle applied to a toothed clutch set between miter gears, for reversing a grinding machine. When the stop-rod *A* is shifted endwise it moves the lever *B* over, and the left-hand end of [illegible] clutch into mesh. Simultaneously the plunger *C* [illegible] the action of the coiled spring, and its bevel [illegible] beveled end of the short extension on *B*, thus [illegible] into full engagement,

and holding it there until reversal again occurs. Another example of the spring plunger arrangement is illustrated in Fig. 20. This design is taken from the clutch-reversing mechanism of a special gear-cutter. The locking is effected by a roller *A* mounted in a stud or plunger, and forced outward by a spiral spring contained in the holder. As the lever *B* is thrown over by the long lever pivoted to

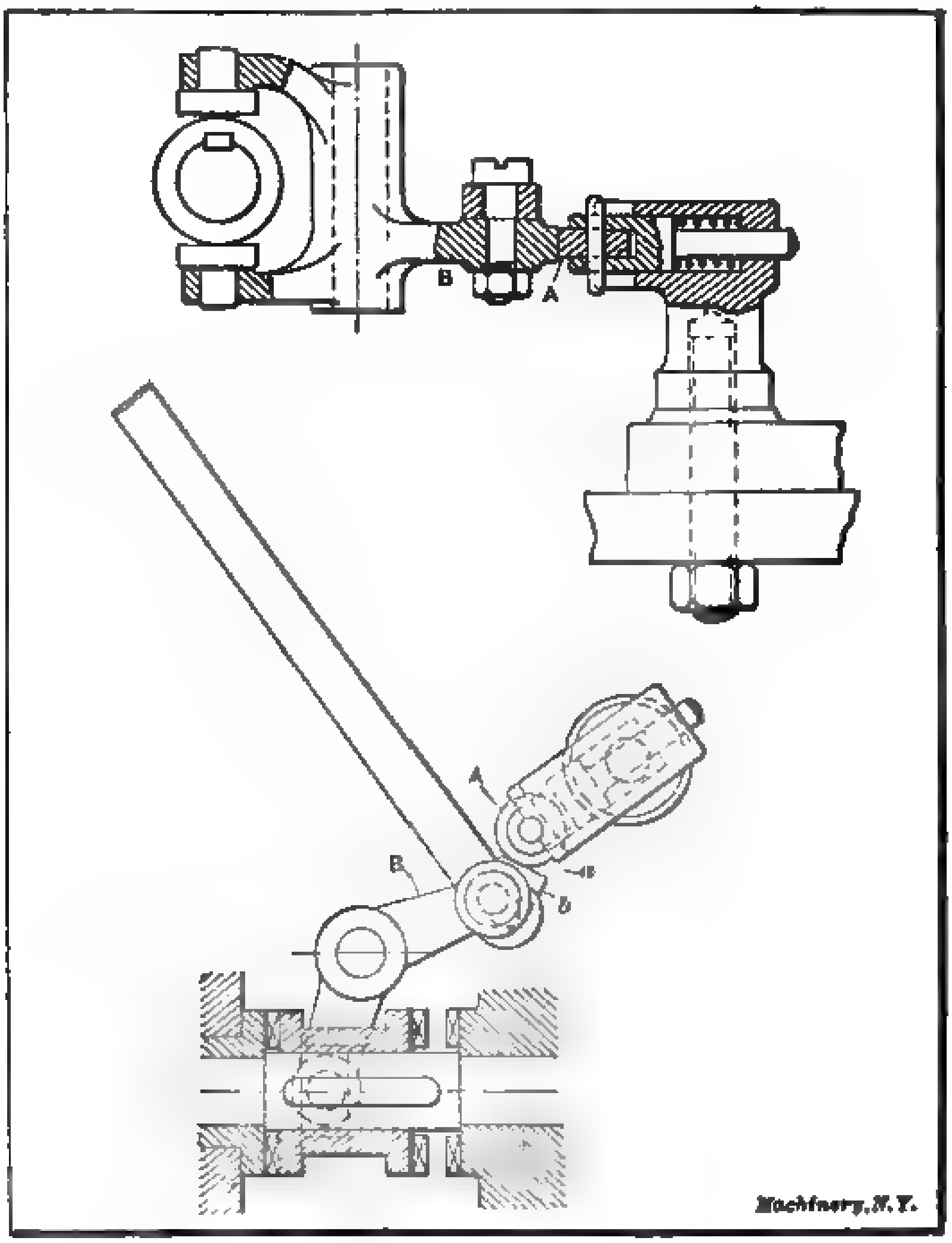


Fig. 20. Spring Plunger applied to Clutch-reversing Mechanism

it, the roller is moved from the flat face *a* to the face *b*, thus retaining lever *B* in position.

Another method, see Fig. 21, utilizes the bent end of a flat spring *A* to lock the beveled end of a lever in its two positions. This example is taken from a shaping machine, in which the dogs *B*, bolted to the T-slot in the top of the ram, encounter the trip lever *C* and throw it over, thus actuating the two connecting levers which move the lever *D*, the latter sliding the rod which throws in the friction clutch

inside the belt pulleys. *E* is a wedge, adjusted in either direction by the screw and knurled nut, by which fine adjustments in length of stroke are obtained while the machine is running.

In cases where a clutch is thrown over by the part rotation of a spindle, the latter may be utilized in connection with the locking as

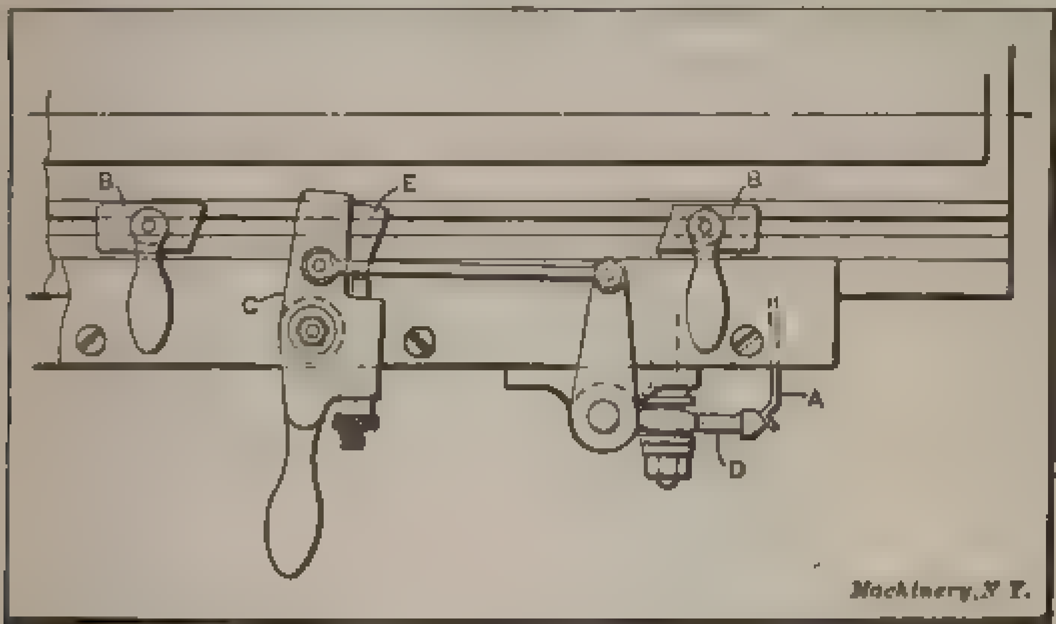


Fig. 21. Spring Locking Arrangement for the Shaper-reversing Mechanism

in Fig. 22, which shows a mechanism for a milling machine table. A plunger is situated at *A*, which catches in the stud inserted in the spindle below, and retains the latter in position. The part rotation of the spindle is effected through a plunger rack *B*, meshing with the

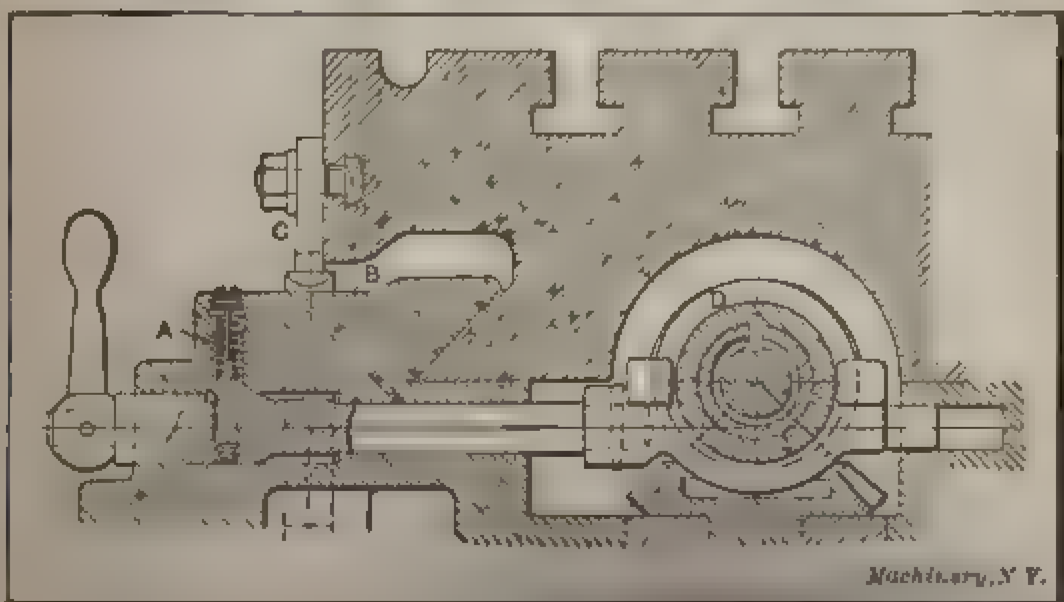


Fig. 22. Locking Mechanism for Clutch for Milling Machine Feed-screw

teeth cut on the spindle, and forced ... y the bevel-edged dog *C* on the edge of the table. *D* i... thrown into gear by the movement of the spind... 'able feed-screw into action.

Worm trips are very much in f... plicity and their instantaneous effect Th... simply released and falls by the action ... g the

teeth from those of the wheel. Two examples of this mode of action will suffice. Fig. 23 is a trip applied to an upright drill, in which the end of a lever *A* is struck by the downcoming collar or rod on the spindle sleeve, raising the other end of the lever, which is formed as a trigger, and releasing the handle *B*, which is clamped to the worm-box, pivoted at point *a*. The worm-box and handle turn on the axis passing through *a*, and thus the worm is allowed to fall away from its

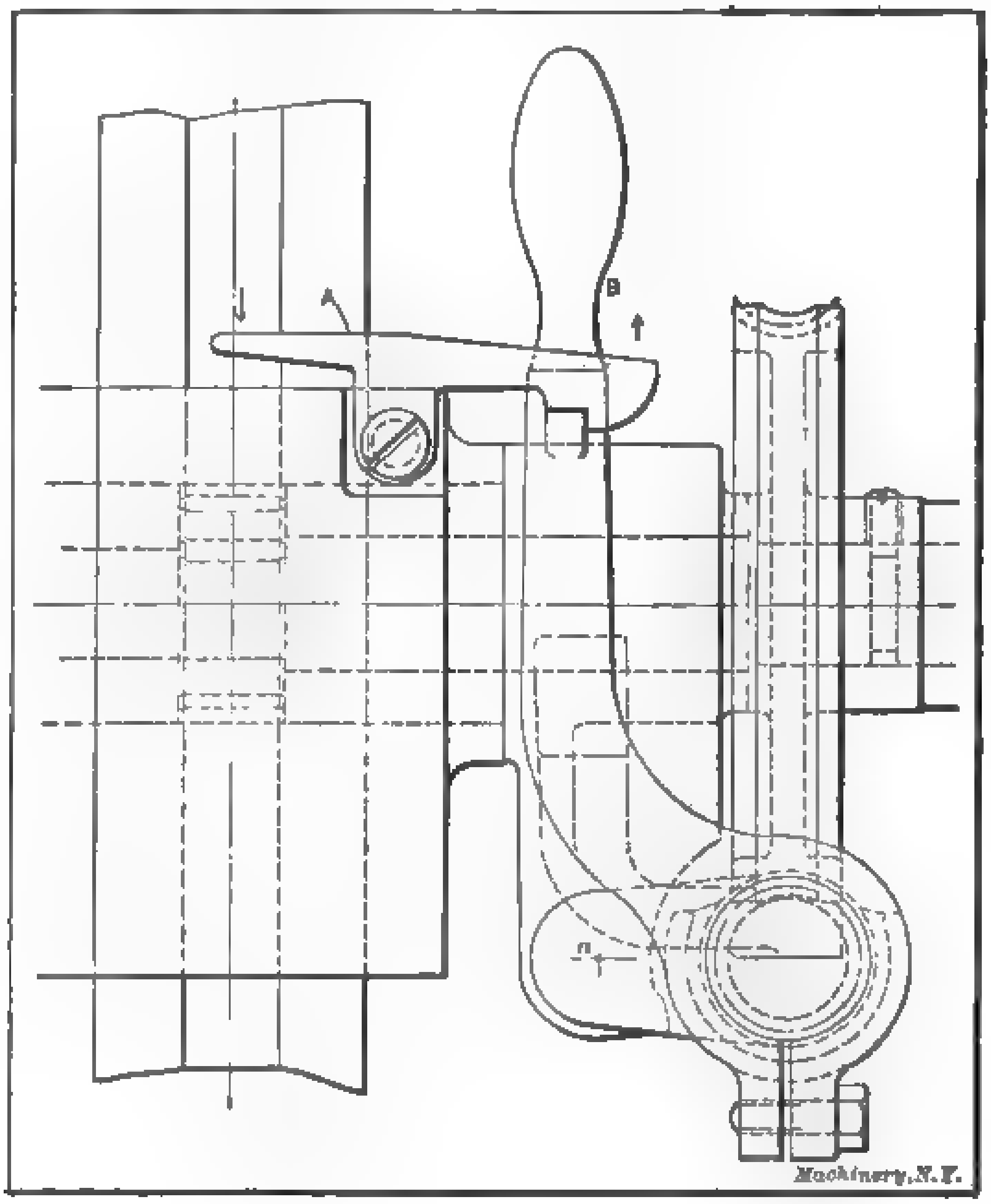


Fig. 23. Trigger Trip for Drop Worm-box

gear. The striking of the lever *A* is generally accomplished by an adjustable collar, clamped at any desired position on the spindle sleeve, or by a rod, as in Fig. 24, held in a stud projecting out from the sleeve.

Fig. 25 is a drop latch fitted to the table of a vertical milling machine, which drops the worm from engagement with the gear that turns the table screw. So long as the latch *A* remains in the position shown, maintained by the spring plunger *B*, the shoulder cut retains the end of the worm-shaft bearing in place, but when

on the under side of the table comes against the short end of *A*, the latter is tilted, and the worm drops.

With regard to belt-shifting mechanisms, the difficulty of producing the necessary amount of belt travel with a small amount of stop lever movement is overcome by magnifying the effect by a series of long belt levers. The operating tappet mechanism is comparatively simple, comprising in general a striking dog *A*, Fig. 26, which knocks over the lever *B*, connected by other levers with the belt-shifting mechanism. The return of the lever *B* is produced by the other dog or tappet *C*, the catch of which can be tipped up, out of the way.

The fitting of trip motions to disks is adopted in various ways, a stop-block being usually bolted to the disk so that at a predetermined

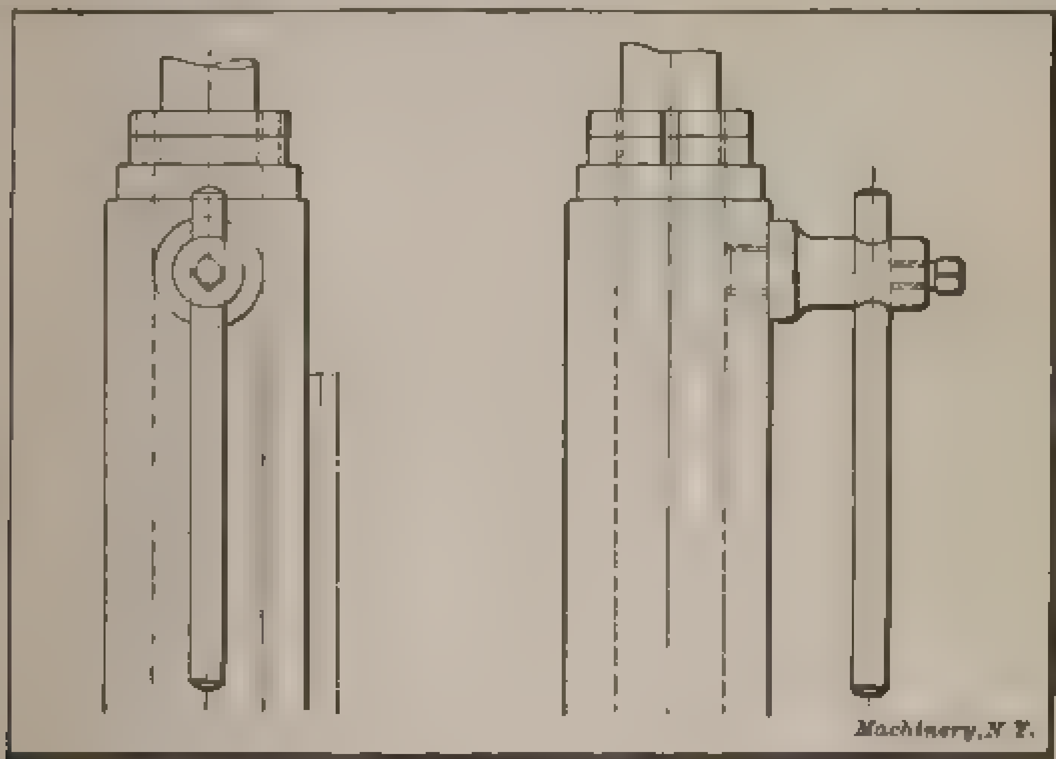


Fig. 24. Trip Rod Fitted to Drill Press Sleeve

point, the block actuates the trip gear and throws out a certain movement. Thus in Fig. 31, the worm-wheel has dogs bolted to a T-slot in its face, and these dogs strike a swinging lever *A*, thus imparting a partial rotation to the shaft on which it is keyed, and dropping, through a rack and pinion, a slide which carries a sector gear that has to be disengaged. The spring plunger and roller *B* keep the lever *A* in either of its two positions, the roller pressing on one or the other of the two slopes of the beveled end. Another interesting application of the disk trip is illustrated in Fig. 29, which shows the end of a boring mill cross-rail. When the clutch *C* is in gear, the feed-screw *A* is turned by a gear *B*, operated from other spur gears not shown. A worm-wheel *D*, with a T-slot in its face for carrying a dog *E*, is driven by a worm on the extension of the screw *A*. herefore, the clutch is in mesh, the wheel *D* continues to rotate contact with the beveled end of the trip lever *F*, and

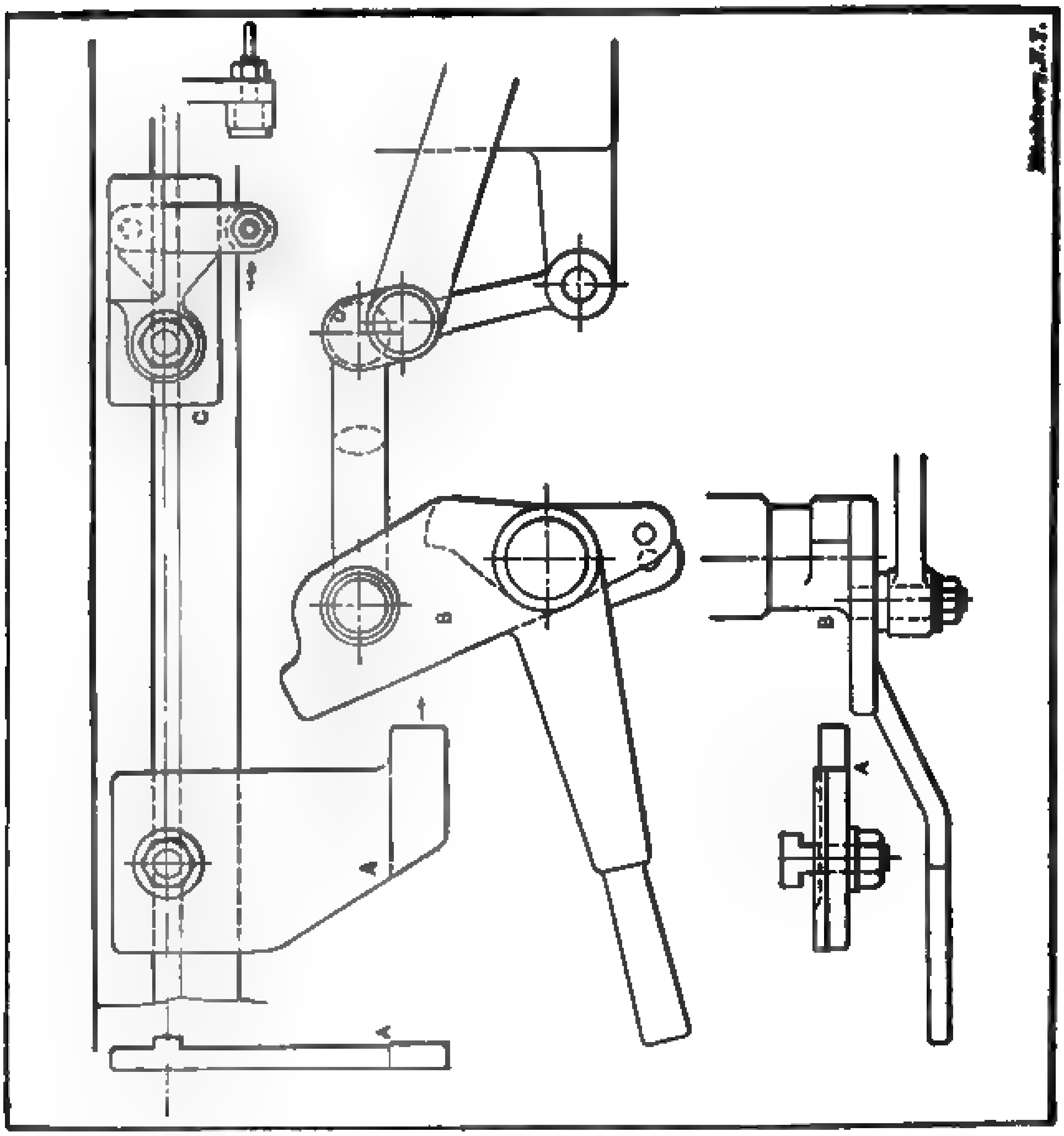
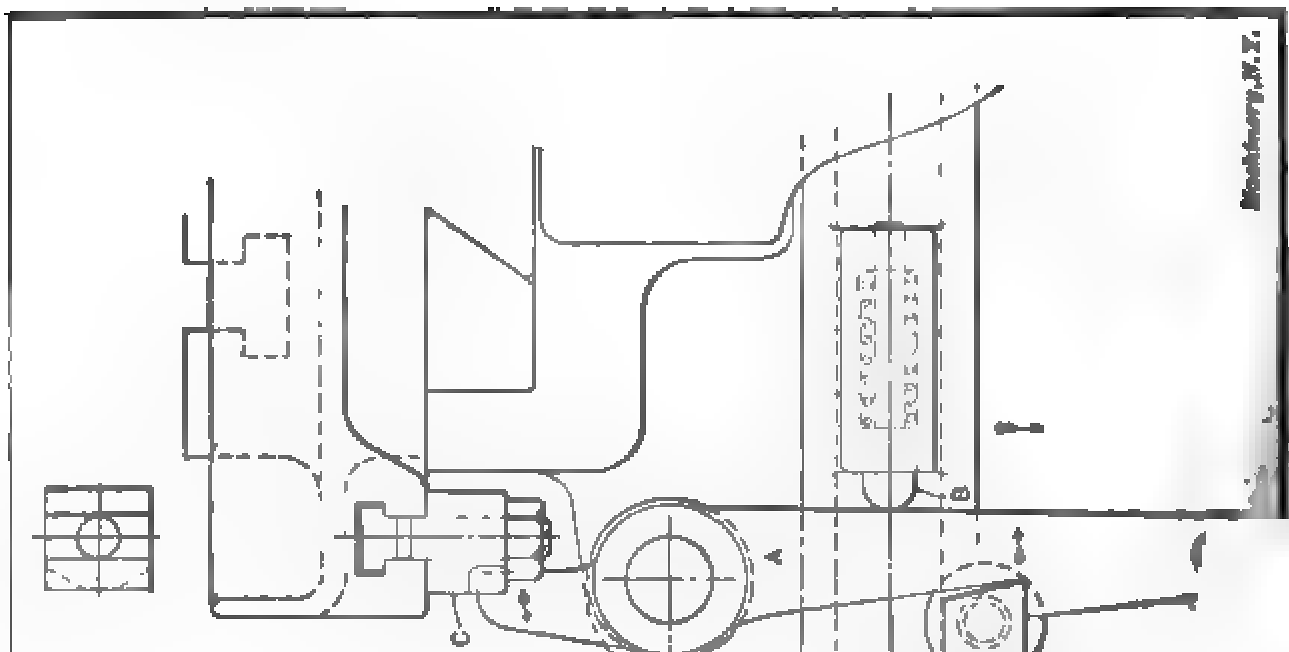


Fig. 26. Belt-shifting Mechanism for Planer



... for Milling Machine

the latter is pushed over, disengaging the clutch, and stopping the rotation of *A*. Dog *E* is set at any required position on the circle to trip the feed at the desired position of the cross-slide on the rail. Another variation of the same idea is shown in Fig. 28, illustrating a feeding device for a gear-cutter. A slotted lever *A* is rocked to and fro, and by means of the pawls *a* gives intermittent turning movements

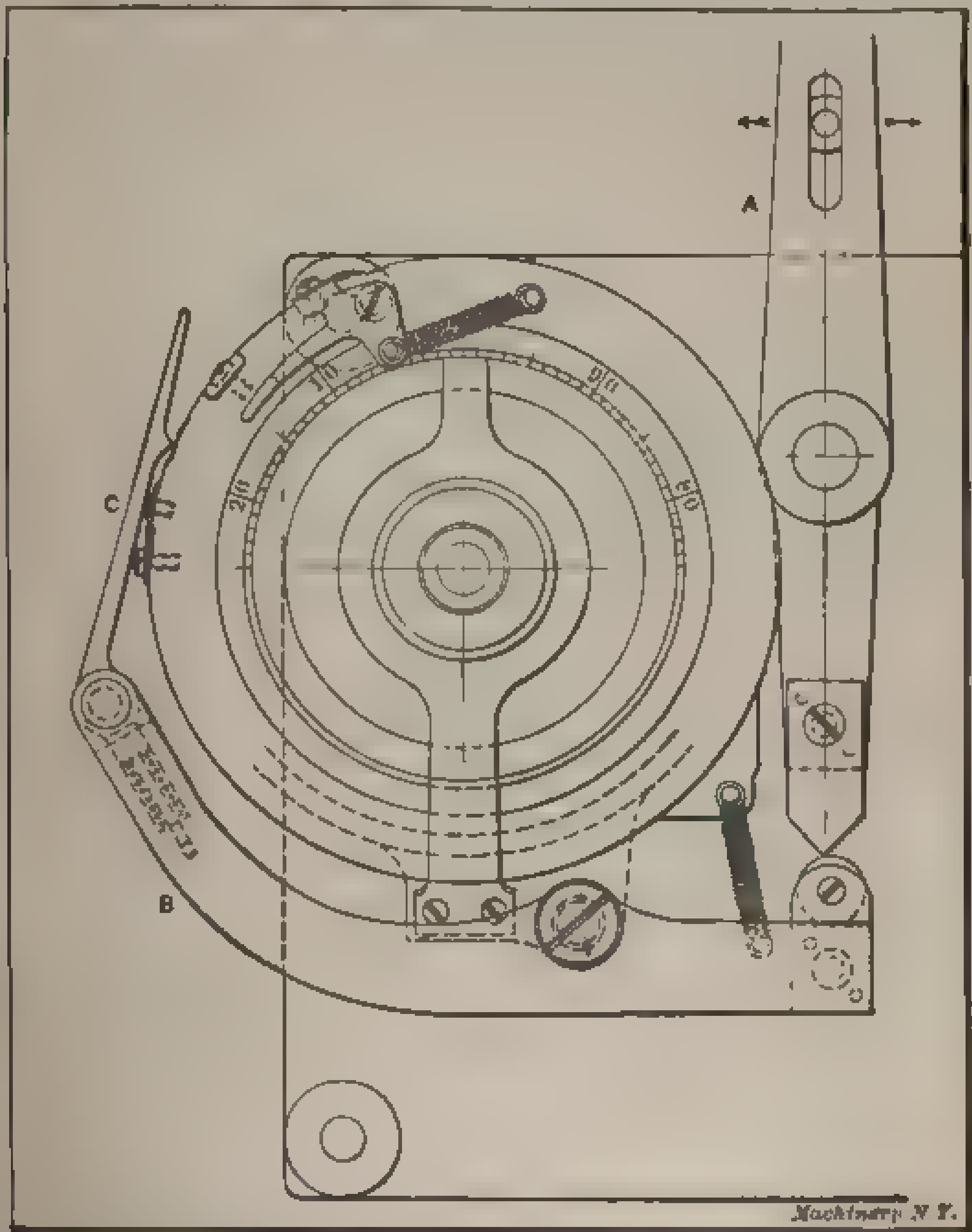


Fig. 27. Combined Reversing and Feeding Mechanism for Grinding Machine

to the ratchet wheel *B*. This continues until the dog *b* comes in the way of the pawls, which are then thrust out of engagement with *B*, thus stopping the feed.

In certain cases the feed is engaged automatically at the same time that the reversal occurs, as in planers. An interesting device, applied ...lly to the Richards' side planing machines made by Geo. Richards ...ester, is used for giving the down feed to the tool- ... the end of the long arm. When the saddle *A*, ...d *B*, propelled by its screw turned by belt

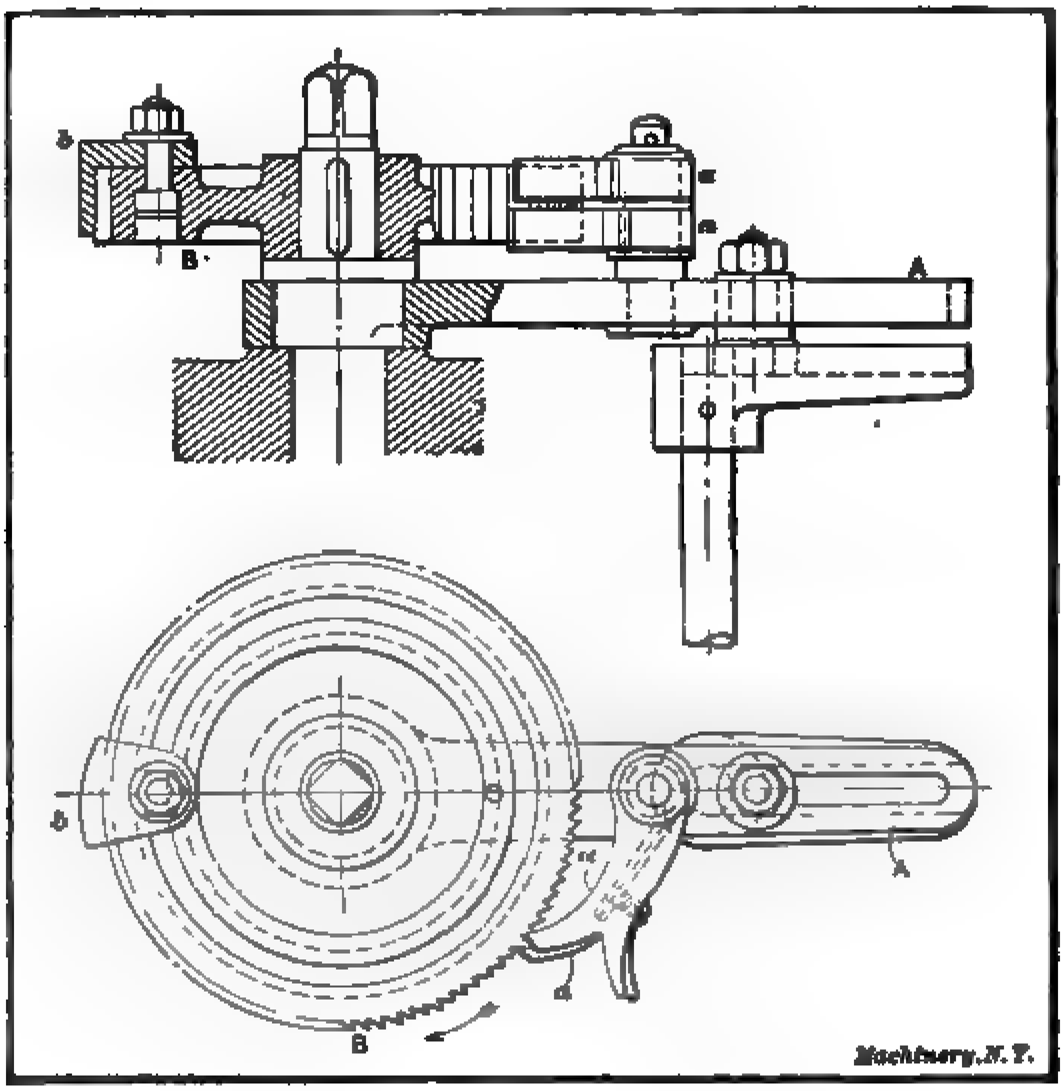


Fig. 28. Ratchet Feed Trip for Gear-cutter

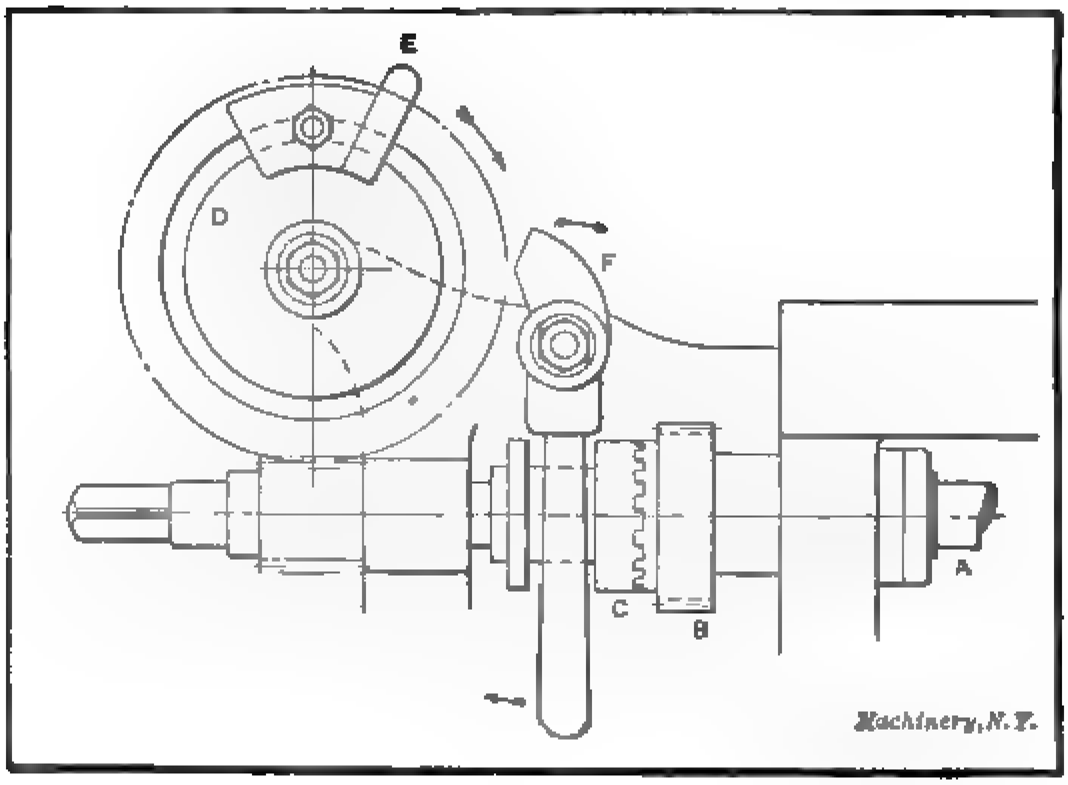


Fig. 29. Trip of the Disk Type used on a Boring Mill

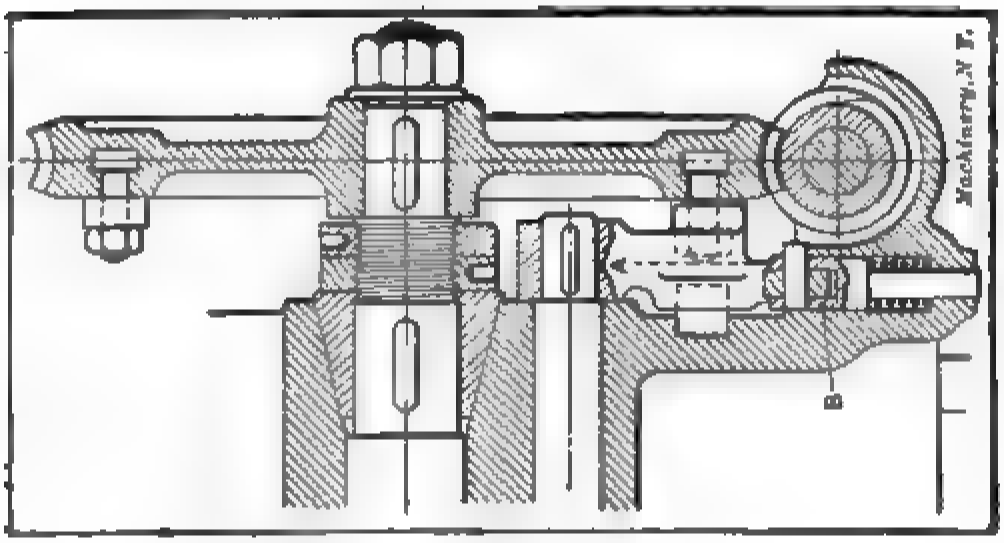


Fig. 31. Trip Actuated from Worm-wheel

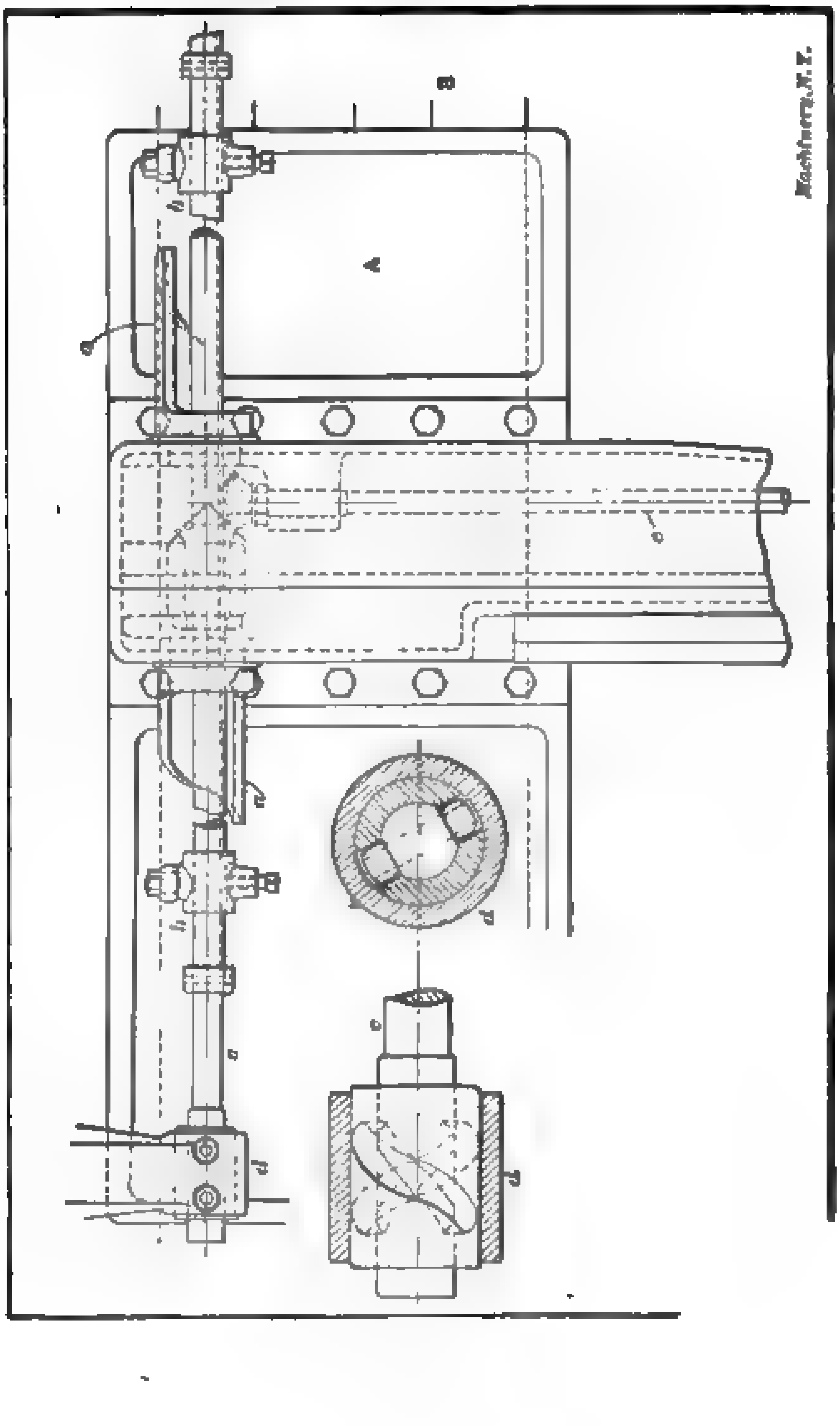


Fig. 30. Combined Reversing and Feeding Mechanism for Side Planer

pulleys with open and crossed belts, a pair of horns *a*, bolted to *A*, strike dogs *b*, mounted on a rod *c*, which by its longitudinal movement actuates the belt-shifting mechanism and produces the reversals, as in an ordinary planer. But the rod *c* is also given a twisting movement, in the following manner: Within the bearing *d* is a bushing, having cam grooves cut in its walls as shown in the enlarged detail, these grooves receiving rollers on the ends of a pin that passes through the rod *c*. When therefore *c* is slid endwise it must twist the rod, because the bushing cannot turn. Another rod *e*, through the medium of miter gears, imparts the down feed to the screw of the tool-box through a ratchet gear.

The combined reversal and feed is also applied to grinding machines, to feed the wheel a slight amount after each pass or stroke. One illustration of this class of mechanism as fitted to the Birch grinders is seen in Fig. 27. The rocking of the lever *A* in alternate directions when struck by the table dogs has the effect of rocking *B* up and down, and causing the spring-maintained pawl *C* to feed the disk, on the periphery of which fine ratchet teeth are cut. Hand adjustment is obtained by the small lever seen near the top.

CHAPTER II

CLAMPING AND LOCKING DEVICES APPLIED TO MACHINE TOOLS

Devices for clamping and locking various parts are found on practically all machine tools, and the different methods used afford a very interesting study. In considering this subject we disregard permanent fastenings—that is those which are not released and tightened as part

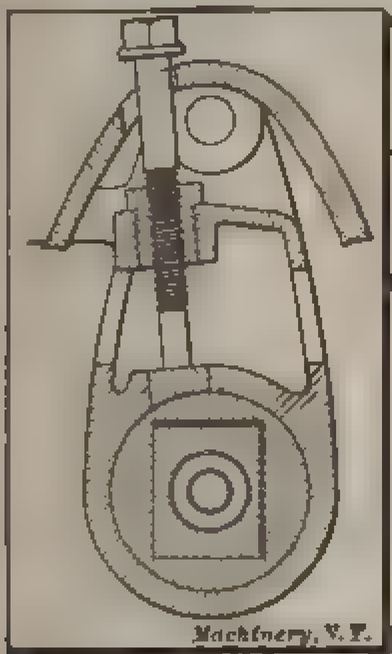


Fig. 32. Set-screw with Shoe for Clamping Sleeve

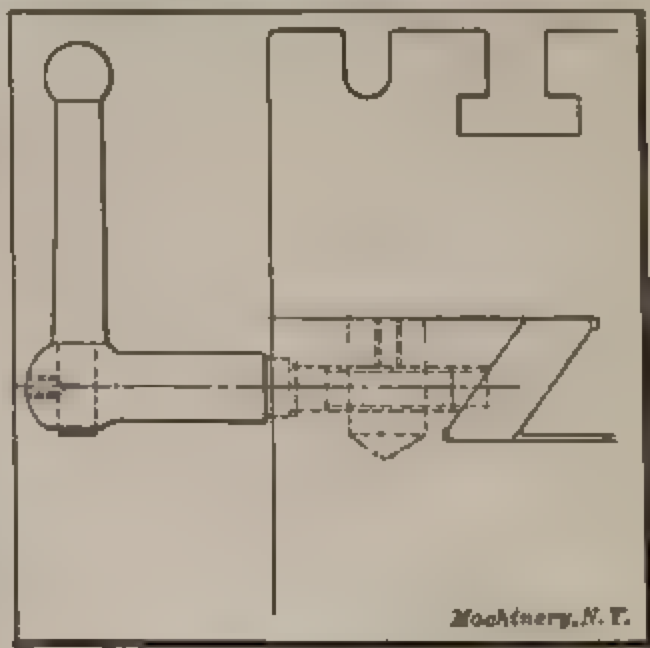


Fig. 33. Screw Recessed into Strip for Clamping Slide

of the operation of the machine—and take into account only those devices which are expressly designed to permit of more or less rapid loosening and tightening, to allow adjustments. There are a great many conditions under which these devices are required, and the par-

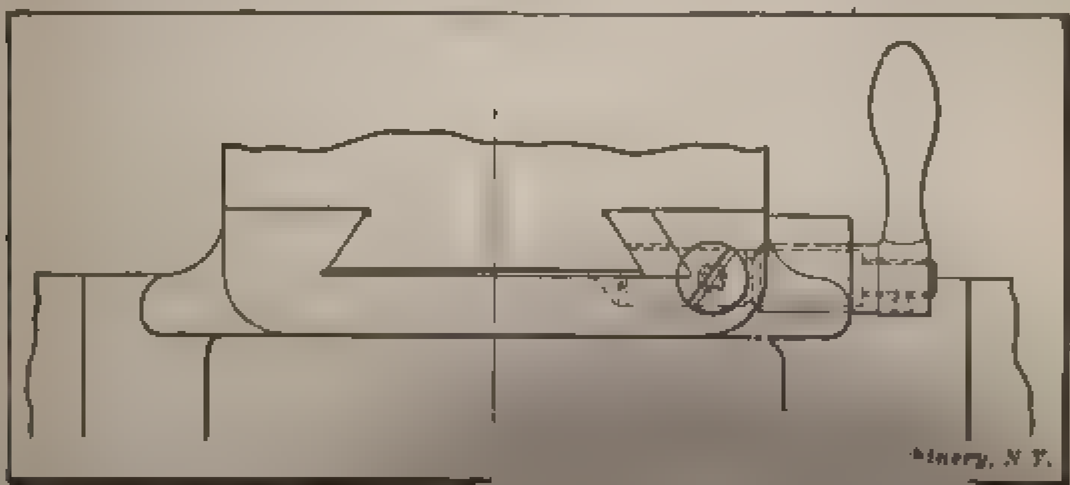


Fig. 34. Screw and

ticular type adopted may va   that is
exactly suited to one case n   For
instance, the pressure from   nt for

holding some parts, but in other cases this would be an unsatisfactory method to adopt. Again, friction may be ample to hold a certain part, while in another case a positive device is necessary.

The distinction between clamping and locking which will be made in the following is this: Clamping produces a decided pressure, suffi-

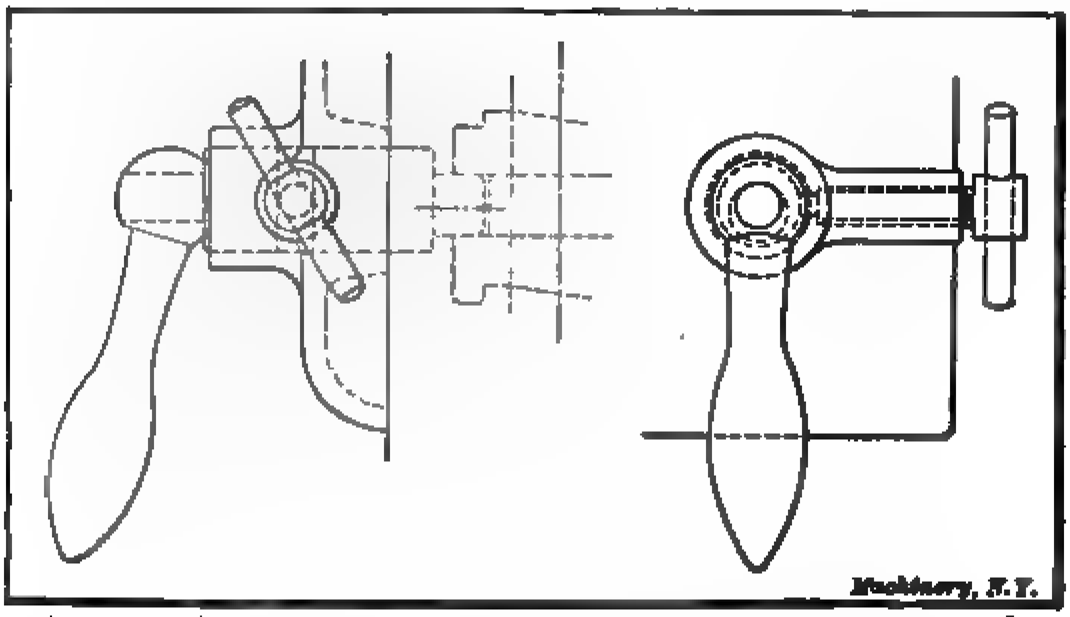


Fig. 35. Clamping Screw with End entering Groove for Clamping Stud

cient to enable a part of a machine to resist the shocks or vibration tending to shift it, while locking is only a method of temporarily holding a piece in position, by means of a plunger or other medium, suffi-

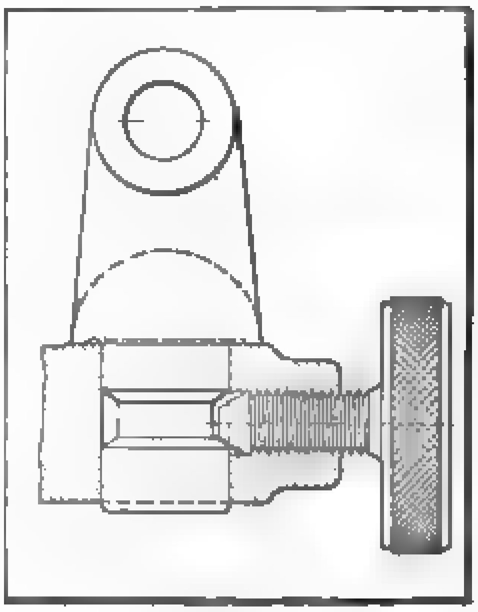


Fig. 36. Clamping Screw with Pull-down Action for Clamping Bearing

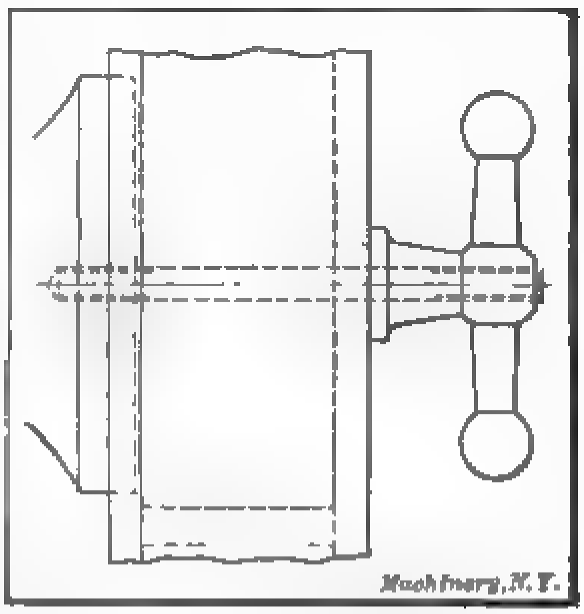


Fig. 37. Bolt and Handle for Clamping Drill Head

cient to retain it, but without giving a powerful clamping or squeezing action. A locking device, therefore, might not be powerful enough to act as a clamping device, so that these functions must be regarded as distinct from each other. As a matter of course we say that a slide is locked, when we ought to say that it is clamped, because the parts are drawn together powerfully, and not merely prevented from shifting by a pin or other means. As a general rule it may be said that locking,

holds a machine part in a definite position, or in one of a series of positions previously known, by means of holes, slots, or grooves, which determine these positions; but a part may be clamped at any location,

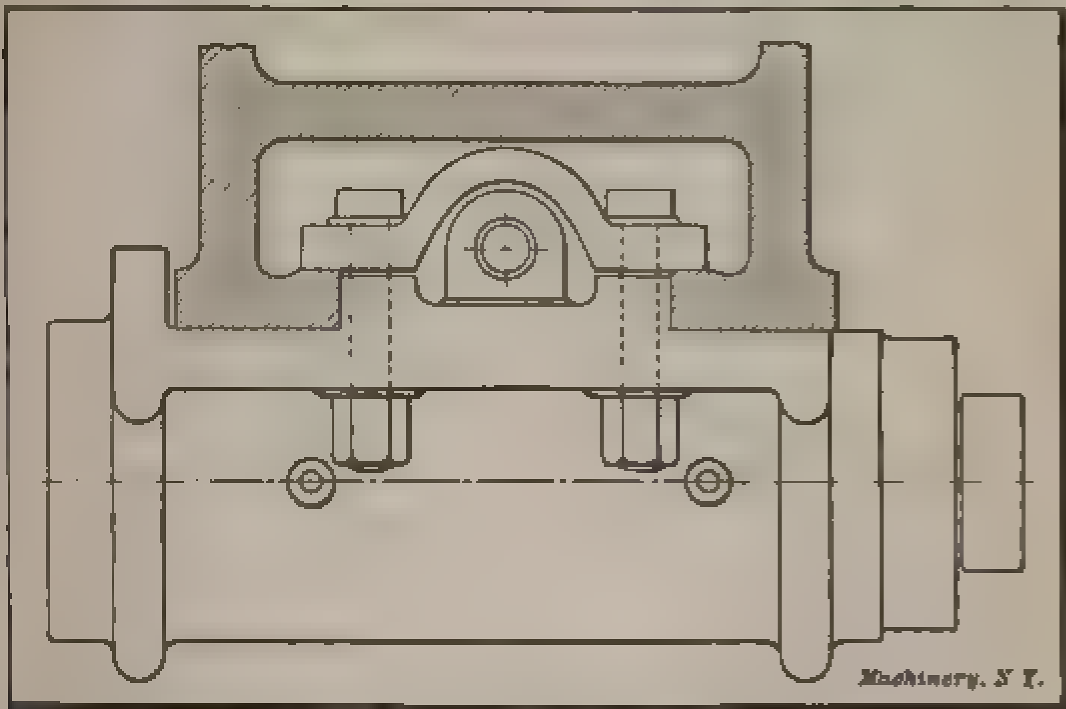


Fig. 38. Showing Use of Bolts and Strap for Clamping

with or without the use of graduations or other means to determine the setting In some cases, although these are not very common, locking and clamping are combined, the latter supplementing and assisting the former.

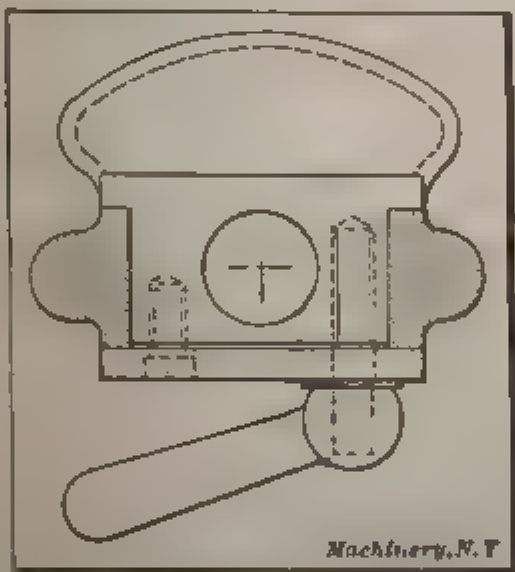


Fig. 39. Clamping Screw Located on One Side

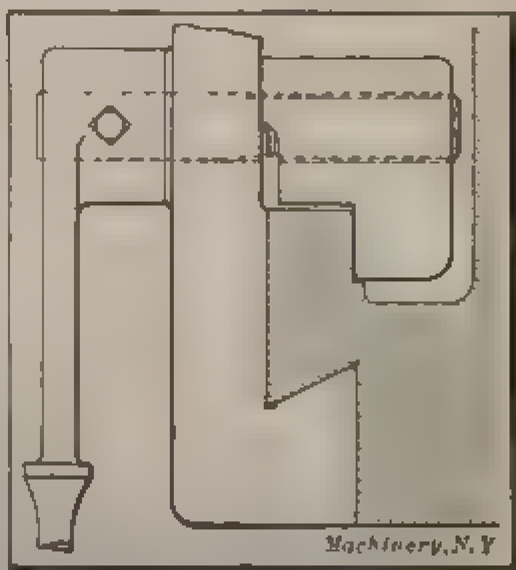


Fig. 40. Clamping Device for Drill Saddle

The following selection of typical devices, representative of American, English, and German practice, will serve to illustrate the principles of clamping and locking devices. A large number of other examples, which might be shown, are but modifications of those here selected.

Clamping De

Dealing first with clamping, the set-screw pressing upon the portion that has heap de-

vice, but is open to objections. On a flat surface it is efficient, but the pressure is too local, and this construction is not adapted to withstand heavy strains without slipping. Moreover it has the bad effect of forcing the parts away from each other when screwed up, so that a fruitful source of vibration is introduced, whereas other and better methods of clamping pull the parts together and act as clamps in the true sense of the word. Usually the pressure of a set-screw point is objectionable,

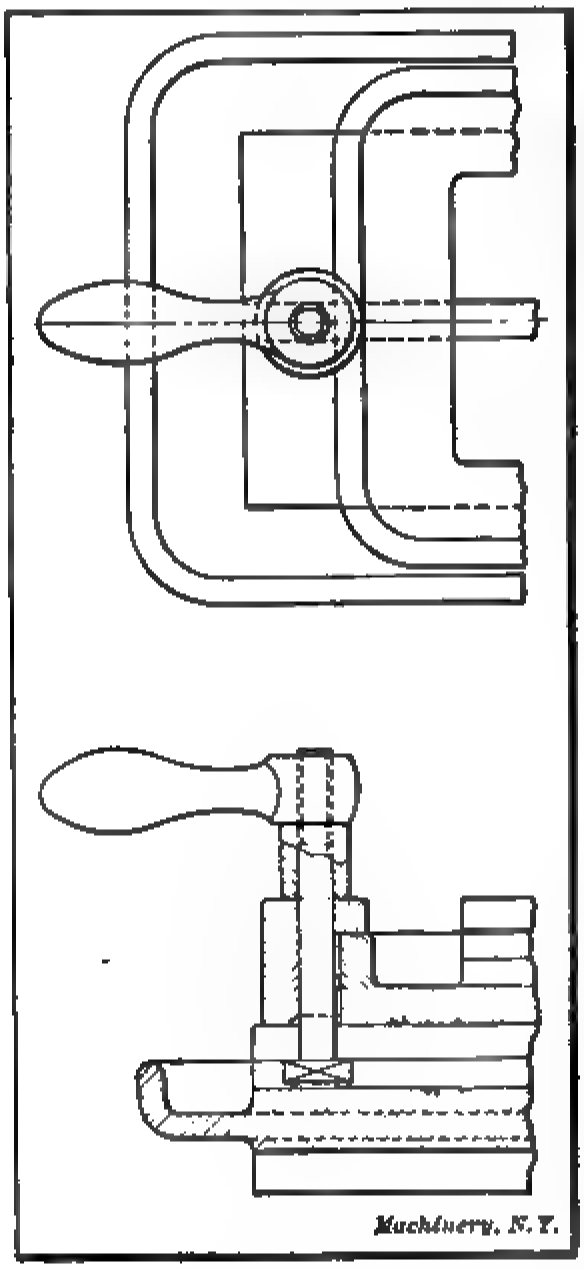


Fig. 41. Clamp for Grinding Machine Swivel Table

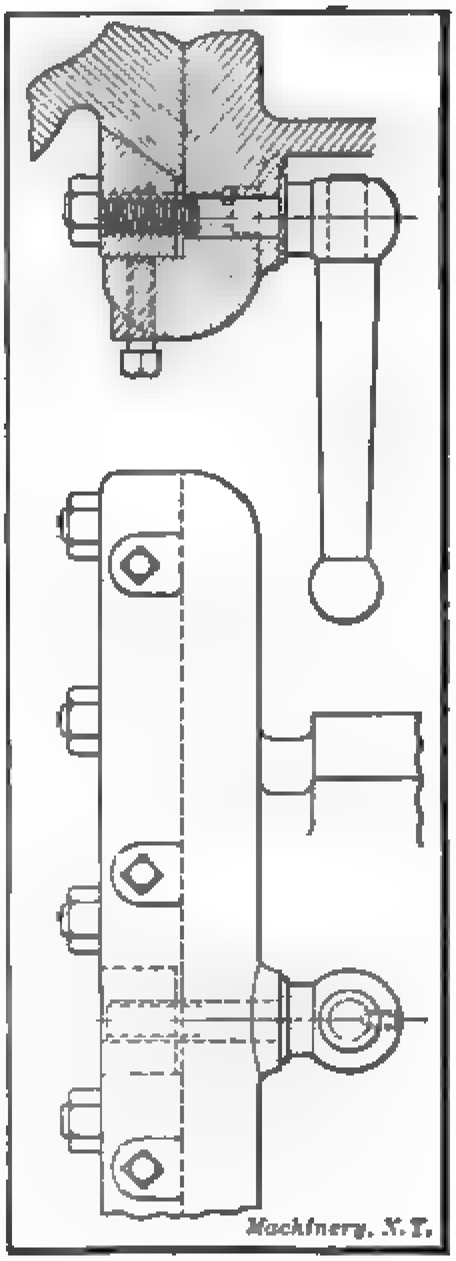


Fig. 42. Clamping Arrangement for V-slide

and a soft pad or shoe is employed to avoid the marring effect otherwise met with. This pad or shoe may be shaped to correspond with the form of the surface against which it bears. Fig. 32 is an example of a set-screw in an awkward situation, this example being taken from one of the Seller's tool-grinders; the screw passes through a bushing, and presses upon a pad shaped to fit the outside of the cylindrical sleeve. In some cases the shoe or pad may be notched out to press against the V of a slide, as in Fig. 34, for locking purposes. This ex-

ample is taken from a cutter-grinder The necessity for a shoe is sometimes avoided by sinking the end of the screw into the metal, as in Fig. 33, which shows a gib clamp for a milling machine slide. In the case of a circular part, Fig. 35, a groove is turned for the locking screw to enter, this construction also preventing endwise motion of the pin to be locked. The function of the pin is to actuate a clutch for a drill-

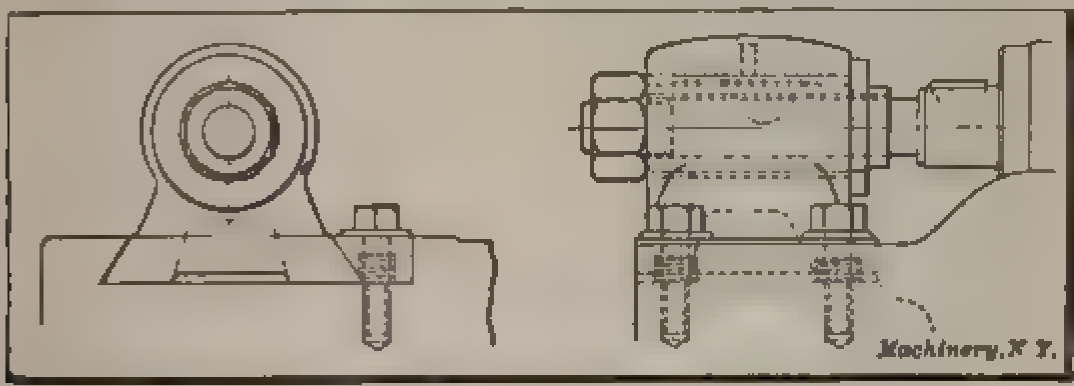


Fig. 43. Clamping Strip with Springs for Raising the Strip when Released

ing machine head Sometimes the groove is arranged so that the screw draws the piece tightly downward to a bearing, as shown in Fig. 36.

There are numerous instances where ordinary bolts are employed for clamping purposes; some special form of clamp or strap is often used in this connection, in order to utilize the pressure to the best advantage. Thus in the work-spindle slide of a gear-cutter, Fig 38, four bolts are

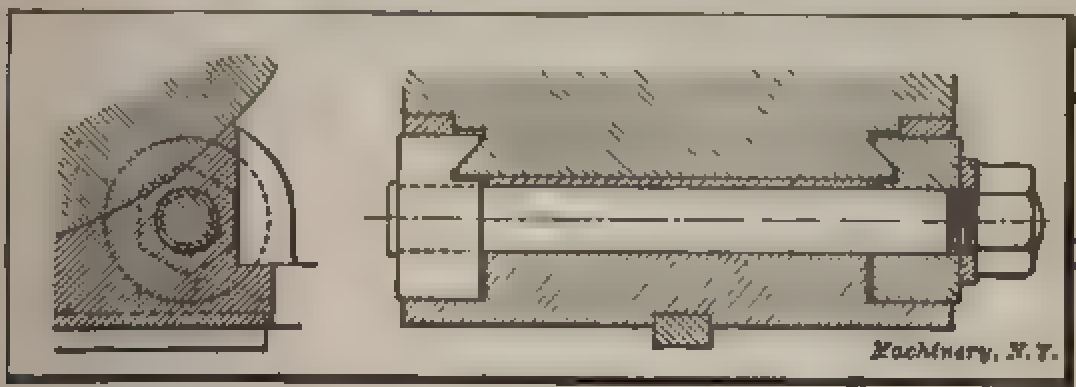


Fig 44. Clamping Action on Opposite Sides of Swivel-block

employed, and a dished clamping plate is used to clear the nut at the back of the slide. When rapid manipulation without using a spanner is desirable, a handle takes the place of the hexagon nut, as on the sensitive drill shown in Fig. 37. Another case where the clamping screw is set to one side, owing to the presence of a central hole, is seen in Fig. 39; a fillister-head screw retains the plate in position on one side, and the tightening of the handle clamps the slide against the face of the casting This detail is taken from a cutter-grinding machine. After some time, a clamping handle will assume a position which renders its proper operation difficult, and provision may be made to compensate for wear to prevent [illegible] trouble. Thus, in Fig. 40, the handle turning the screw whi[illegible] [illegible]lamping block is secured by a set-screw By loosening [illegible] be readjusted into the most convenient [illegible] [illegible]ple represents the clamp for the saddle [illegible]

Fig. 41 illustrates the table clamp of a grinding machine, which permits of the swiveling motion for angular grinding. This design differs from the previous instance in that the bolt is adjustable in its slot to allow for the radial movement of the table. Another specimen of clamping with a block drawn up by a bolt and handle is shown in Fig.

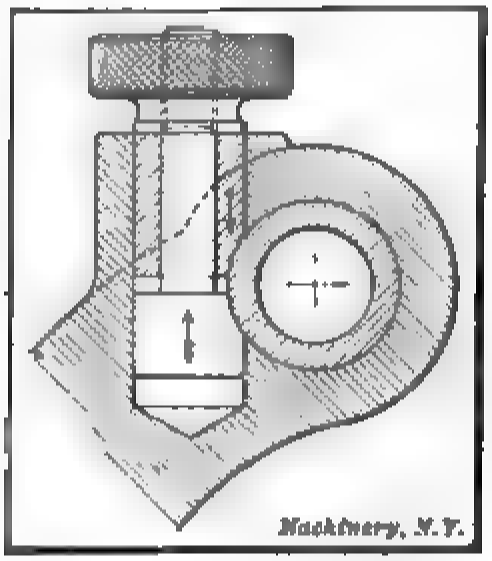


Fig. 45. Clamping with Bolt and Bushing

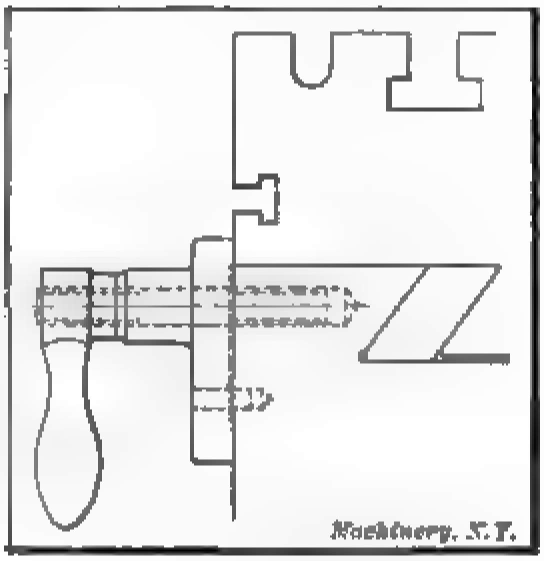


Fig. 46. Clamping Plate for Edge of Milling Machine Table

42, and is used for a milling machine slide. The threaded end of the bolt is tapped into the block, and the latter presses against the beveled edge of the slide. Another variation of this type of device is shown in Fig. 43, illustrating the outer bearing for a gear-cutting spindle. This

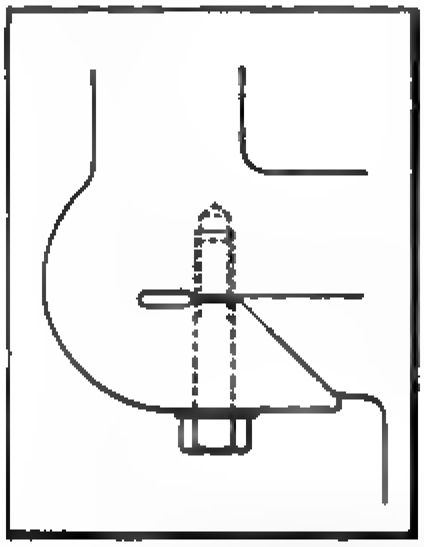


Fig. 47. Clamping Arrangement based on the Spring Action of the Metal

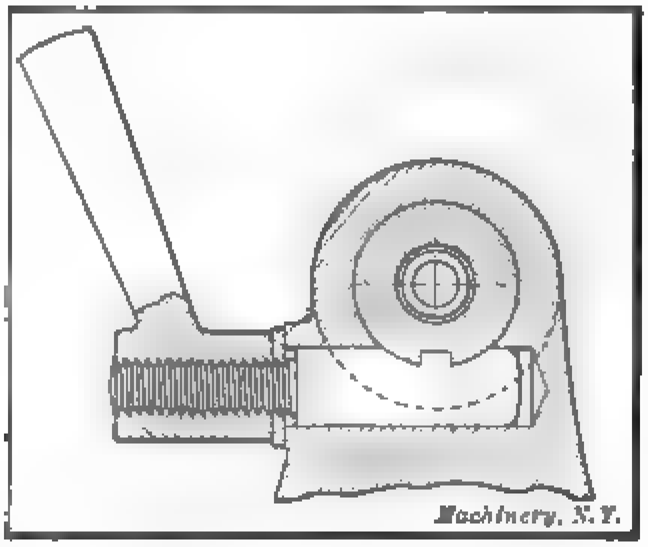


Fig. 48. Clamping Bolt for Poppet or Tailstock Spindle

spindle must be adjusted endwise; by loosening the two set-screws, the clamping strip is raised by the coiled springs, and the bearing is free to slide. Under certain conditions it is necessary to have a perfectly balanced clamping effort, as, for example, in dividing heads. An instance of this is illustrated in Fig. 44. The swivel-block has beveled edges turned at each side, and the correspondingly shaped blocks are drawn together simultaneously by the tightening of the nut, the clamps are guided in the solid metal, so that distortion is prevented. A similar

principle is employed in many classes of clamping devices for cylindrical parts, such as the spindle in Fig. 45, which is secured by the pressure of the bolt head and the bushing, suitably formed to fit the spindle, and drawn down upon it by tightening the nut. The spindle is not marred, and there is no need of weakening the bearing by splitting it for the purpose of clamping.

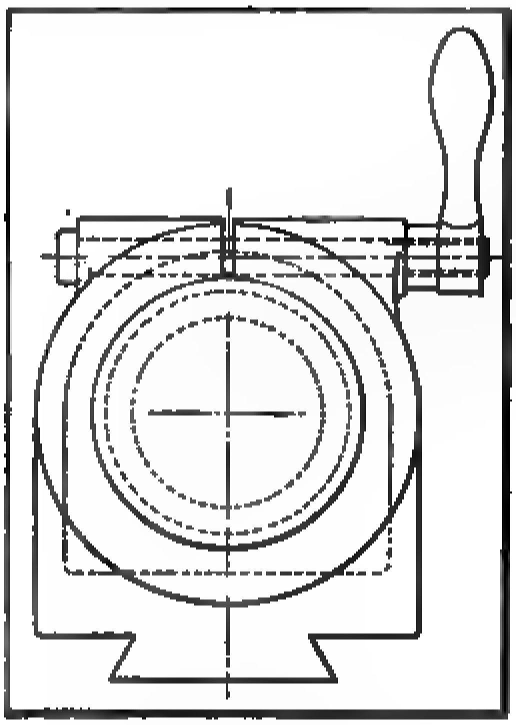


Fig. 49. Method of Clamping with a Split Bracket

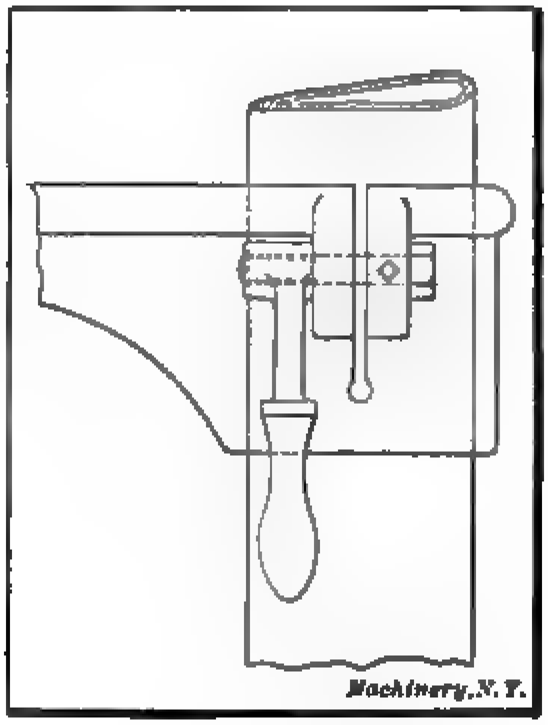


Fig. 50. Clamping a Partially Split Bracket to a Column

Three other types of clamping devices are shown in Figs. 46, 47 and 48, the first being a plate forced against the side of a milling machine table, this being an alternative construction to that in Fig. 33. Fig. 47

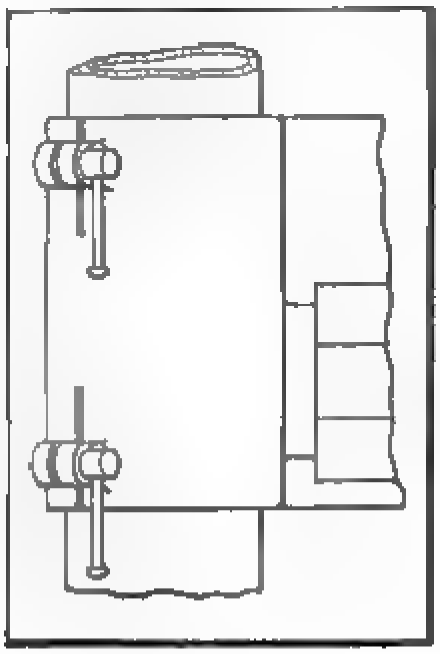


Fig. 51. Sleeve Split at Ends for Clamping

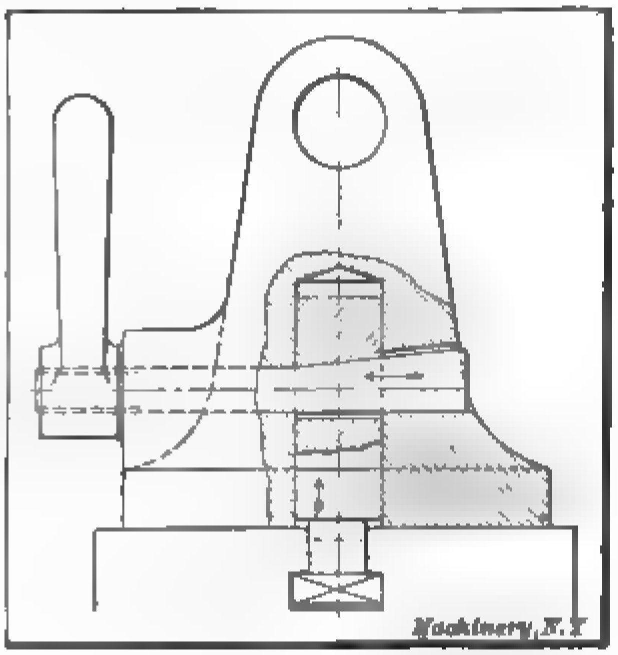


Fig. 52. Example of Wedge Clamping

is a form that is possible in only a few cases, the mental
except for a split or slot, and the clamping effected

action only. This detail shows the method of attaching a milling machine brace to the knee. Fig. 48 shows a clamping arrangement for a poppet or tailstock spindle, which also serves the purpose of keeping the spindle from turning.

One of the most popular methods of clamping is by the split lug, boss

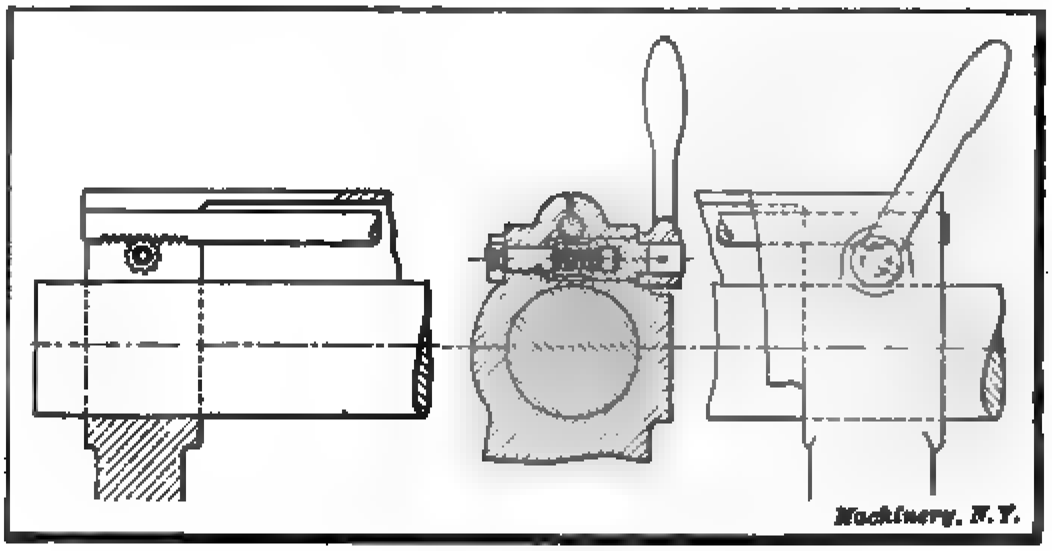


Fig. 53. Clamping Two Bearings simultaneously

or collar, drawn together by a screw or screws. This provides for a very powerful grip. There are so many examples of this device that it is only possible to show a few types. In small lugs, fillister head screws are suitable for the drawing-together action, but a bolt is better for

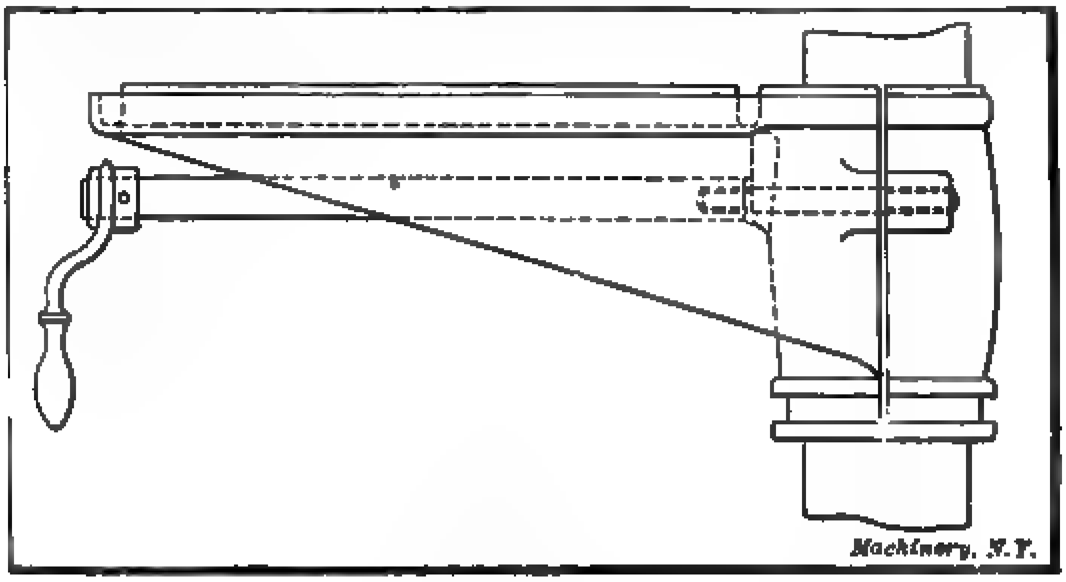


Fig. 54. Clamping Handle carried out to Edge of Table for Convenience of Operation

large parts, as in Fig. 49, which shows the bracket of a cutter-grinder clamped on its pillar. It is not always necessary to carry the split right through the boss; it may pass only partly through, as in Fig. 50. The bolt in this case is held by a set-screw, so that it may be turned partly around to bring the clamping handle into the most convenient position, this constituting a variation of the method in Fig. 40. Fig. 51 is another instance of partial splitting of a sleeve of a radial drill arm. An interesting type of such a method of clamping is found in the Brown & Sharpe milling machine arm; the two tightening screws are

situated at the opposite ends of the frame, but are coupled together by a rack-bar which causes the two screws to turn simultaneously It is, therefore, necessary to turn one screw only, as indicated in Fig. 53.

The tightening nut or lever for a split clamp is usually placed close to the boss, but in some cases it may be necessary to vary the position

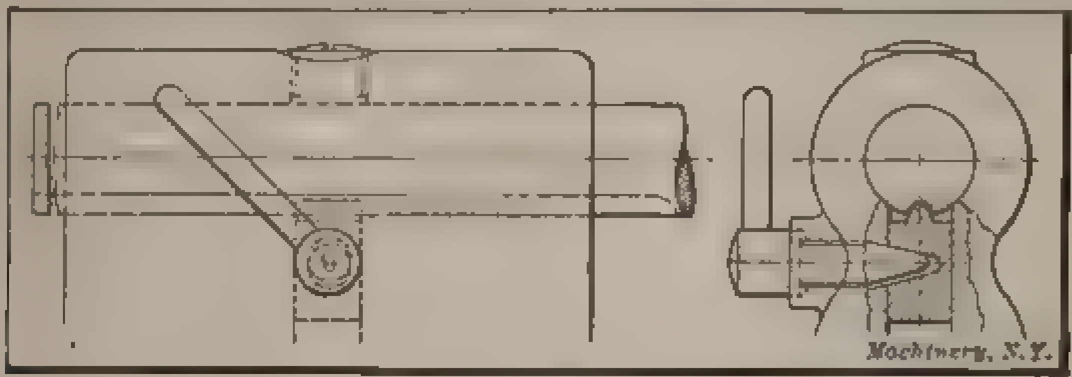


Fig. 55. Wedge Action Clamp for Grinder Tailstock

for convenience of manipulation. Thus in the drilling machine table, Fig. 54, the screw is prolonged into a long spindle, thus bringing the clamping handle to the front of the table, where the operator can reach it without effort or straining. Fig. 60 illustrates a split clamp which does not act in the usual manner, but serves to draw two beveled sur-

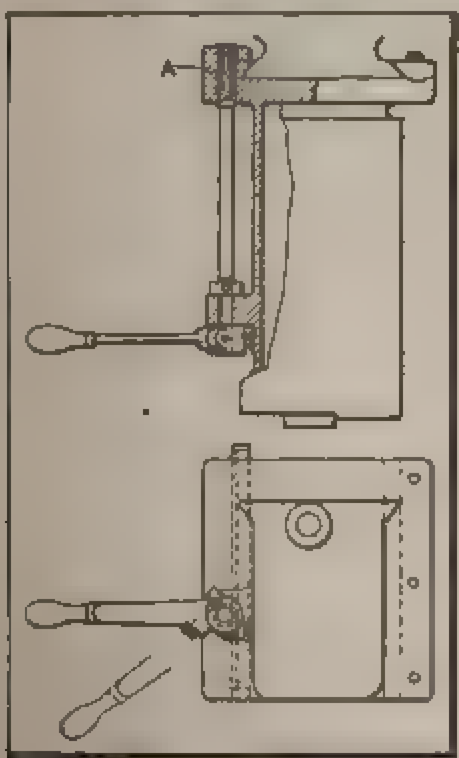


Fig. 56. Long Strip for Clamping Knee of Milling Machine

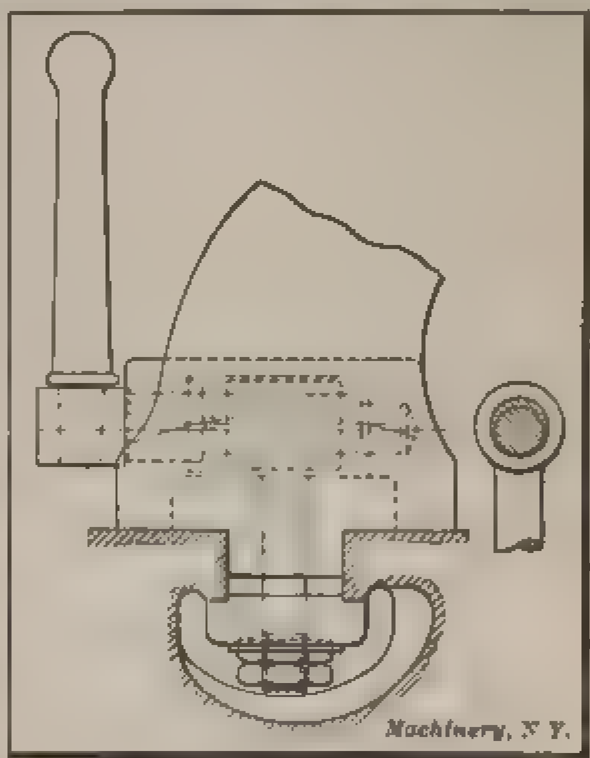


Fig. 57. Eccentric Clamp for Tailstock

faces together (this example being a pillar and sleeve of a radial drill), to prevent rotation. When the clamp is loosened, the sleeve is free to turn on its ball-race.

Wedge action is utilized for clamping, in numerous cases, instead of direct screw pressure, and is often more suitable for certain purposes. Fig. 52 is representative of several such designs, this example being the clamp for a grinder tailsto on is like that of a cotter A

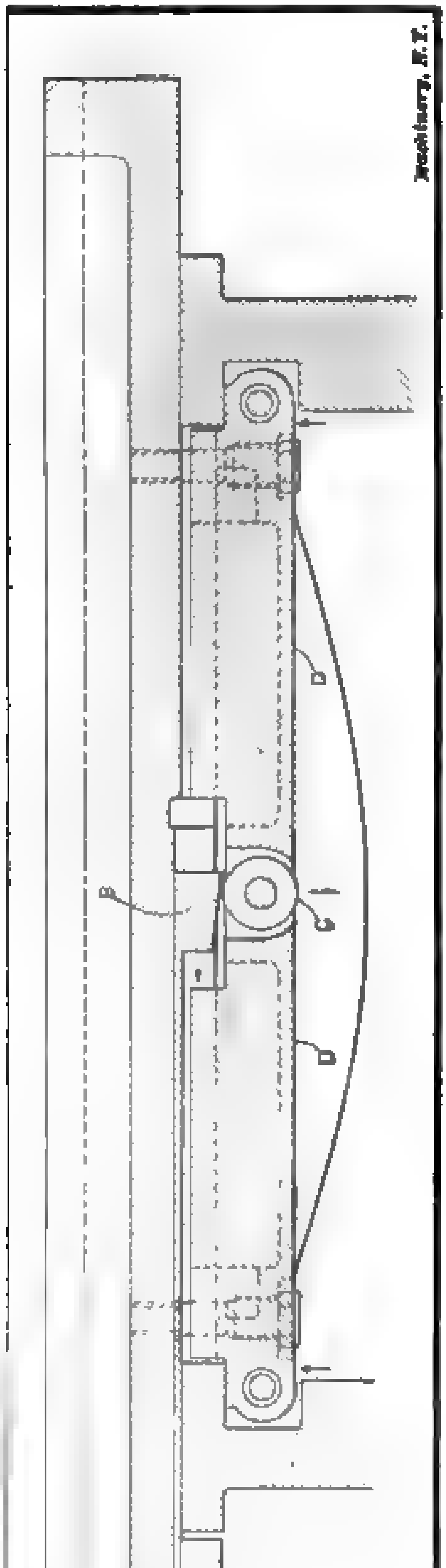


Fig. 58. Clamping Device for Planer Cross-rail

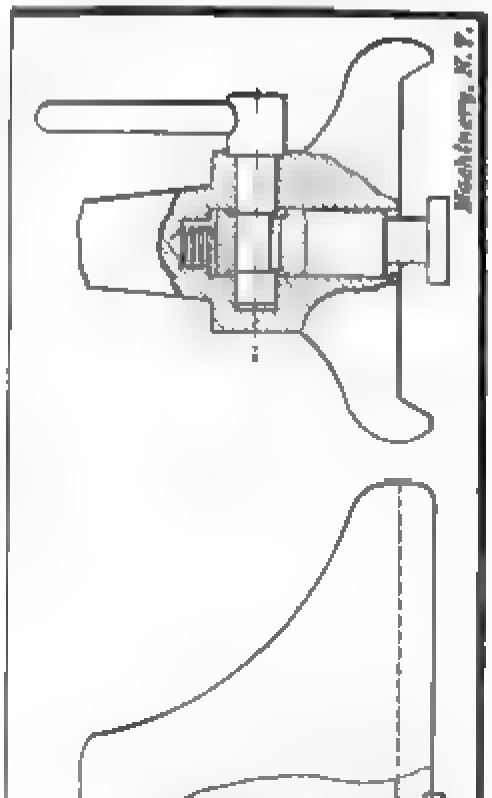


Fig. 59. Eccentric Action Clamping Device used on Bench Lathe

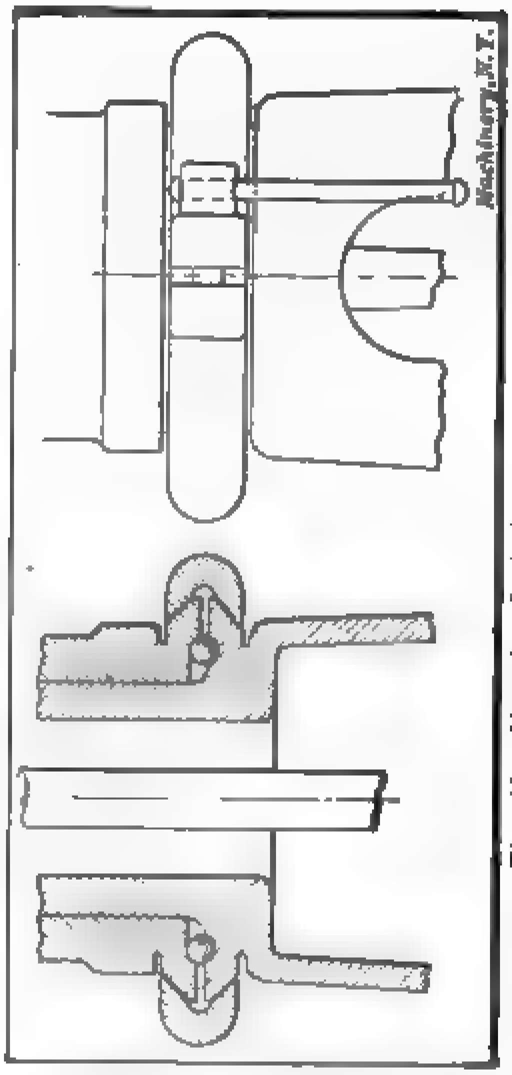


Fig. 60. Clamping Radial Drill Sleeve to Column

similar principle is employed in Fig. 55 where the overhanging arm of a special grinding machine is held by the forcing upward of a block through the screwing in of a tapered plug. The groove in the arm also prevents the latter from twisting.

Fig. 56 shows the principle of a clamping arrangement used by Messrs. Alfred Herbert, Ltd., on their milling machines. The object is

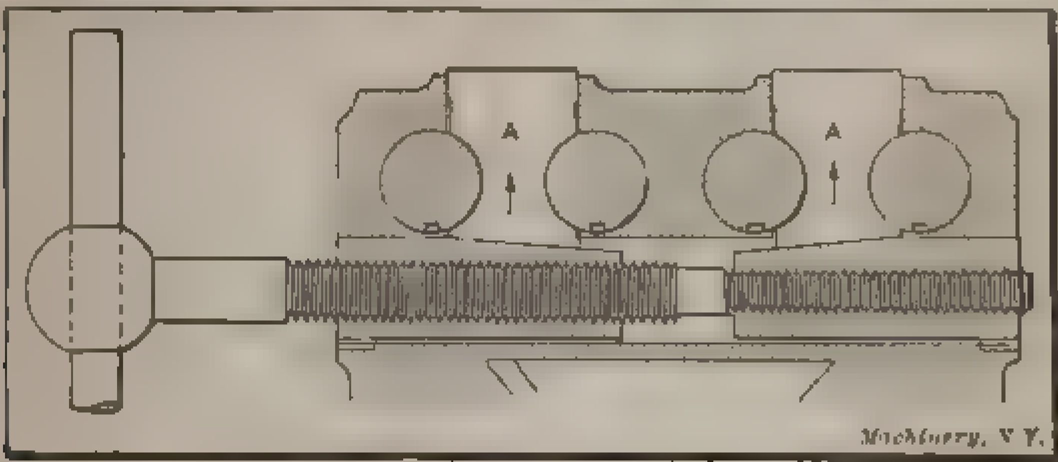


Fig. 61. Clamping Four Spindles simultaneously

to clamp the entire length of the knee, instead of clamping at one location only, the wedge strip being forced downward by turning the handle, which causes the pinion *A* to rotate and force the strip along. Another instance of wedge action combined with levers, is seen in Fig. 58, which shows the Whitcomb-Blaisdell planer cross-rail fastening.

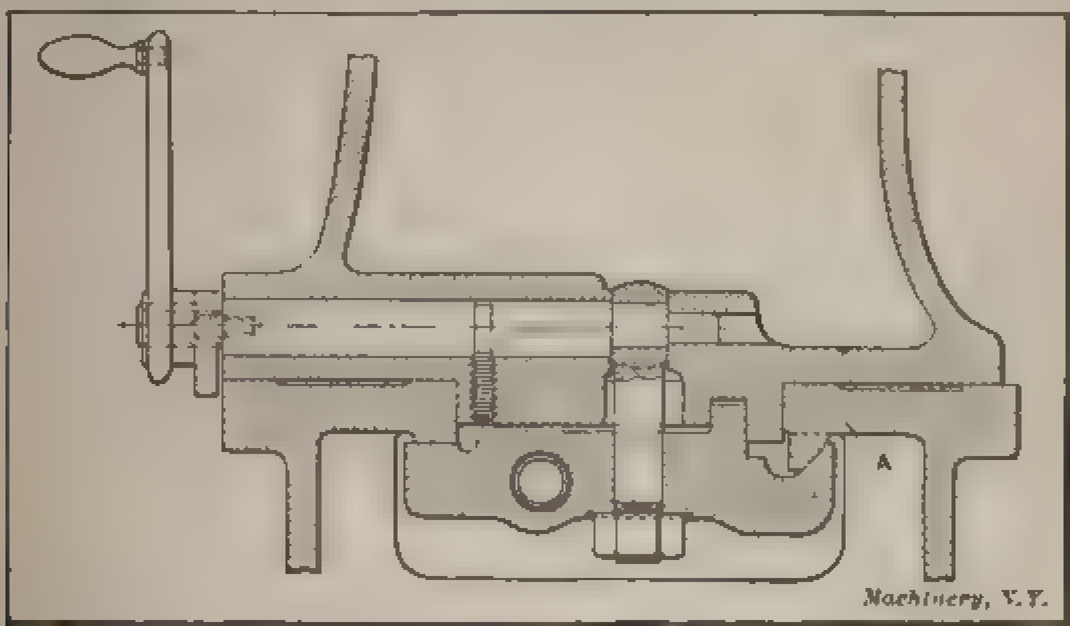


Fig. 62 Eccentric Action Clamping Device used on Chucking Lathe

When the handle in the disk *A* is pulled over, it draws the strip and wedge *B* along, and the latter presses against the roller *C*, which is mounted on the pivot pin of the levers *D* These levers are forced outward, and as they pivot on the screws near their ends, they are caused to press against the inside of the uprights, and thus pull the cross-rail tightly against the faces of the housings. Fig. 61 shows a multiple clamping arrangement, used on multiple dividing centers. The object is to bind the four spindles simultaneously When the right- and left-

hand screw is turned, it draws the two wedges together, and these push the blocks *A* upward, thus binding the spindles.

Eccentric action is also employed extensively, and has the advantage of being more rapid and convenient for some kinds of clamping than a screw or wedge. This action is particularly handy when the clamping and unclamping is very frequent. An eccentric device applied to a lathe tail-stock is illustrated in Fig. 57. The nuts at the bottom of the clamping plate allow for adjustment to make the eccentric act at the proper position of the handle. A modified form of the same type is seen in Fig. 59, which is used for a bench lathe, while an arrangement for the turret saddle of a chucking lathe is shown in Fig. 62. The clamping plate here is designed to pull the saddle over against the edge *A* of the bed, so that a constant alignment is preserved. The tightening lever has stop lugs, which abut against studs, screwed into the face adjacent to the boss, and arrest the lever at definite positions. An instance of duplex clamping, applied to the head of a vertical milling

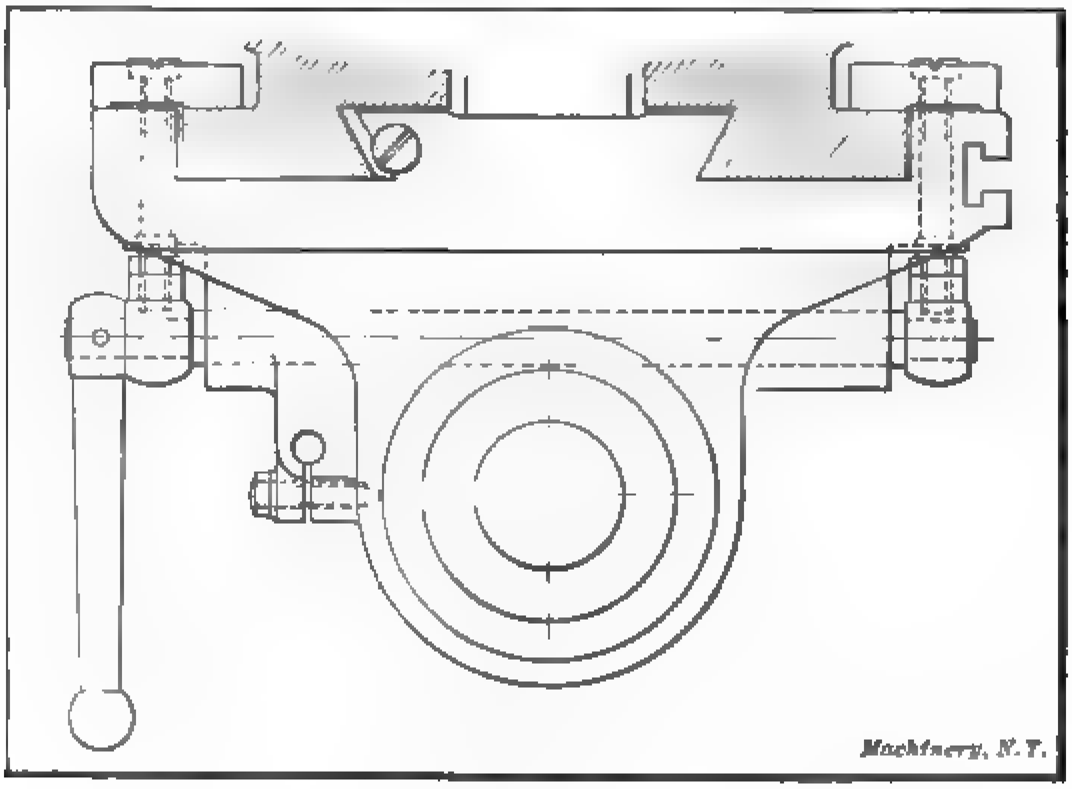


Fig. 63. Eccentric Clamping Arrangement for Vertical Milling Machine Head

machine, is shown in Fig. 63. The clamping rod passing through the casting has slightly eccentric ends, and these force the lugs upon them in an outward direction when the lever is pulled, thus drawing the plates or clamping strips against the back edges of the projecting ways of the column. Adjustment is made by means of the threaded ends and the nuts.

Provision has occasionally to be included for permitting a pivoting or "throw-back" action in connection with clamping. Very frequently a pivoted eye-bolt meets the requirements, or alternatively a loop or strap fitted, as shown in Fig 64, to a hinged steady-rest. A different method is to employ bolts in T-slots, Fig 65, the two marked *A* being used to hold the bracket down, for steadying the arbor support of a

gear-cutter. The bracket is hinged on the pivot-pin in the plate *B*, and the latter remains clamped in position by its two bolts. When the bracket has to be thrown back, it is only necessary to slacken the nuts *A*, and slide the bolts out of the slots. Another point with reference to clamping is that power is sometimes gained by using gears for effecting a specially tight grip. There is one type of lathe tailstock in which the clamping bolt is turned by a spur gear actuated by a pinion, on the shaft of which the spanner is placed, thus giving a very powerful grip for high-speed work.

Locking Devices

Taking up now the consideration of locking devices, it should be mentioned that these may be classified as positive locks and friction locks, the latter being obviously unsatisfactory in many cases where the risk of any slip would be detrimental. The simplest lock, perhaps, is that used for the back-gears of a lathe or other machine, where a

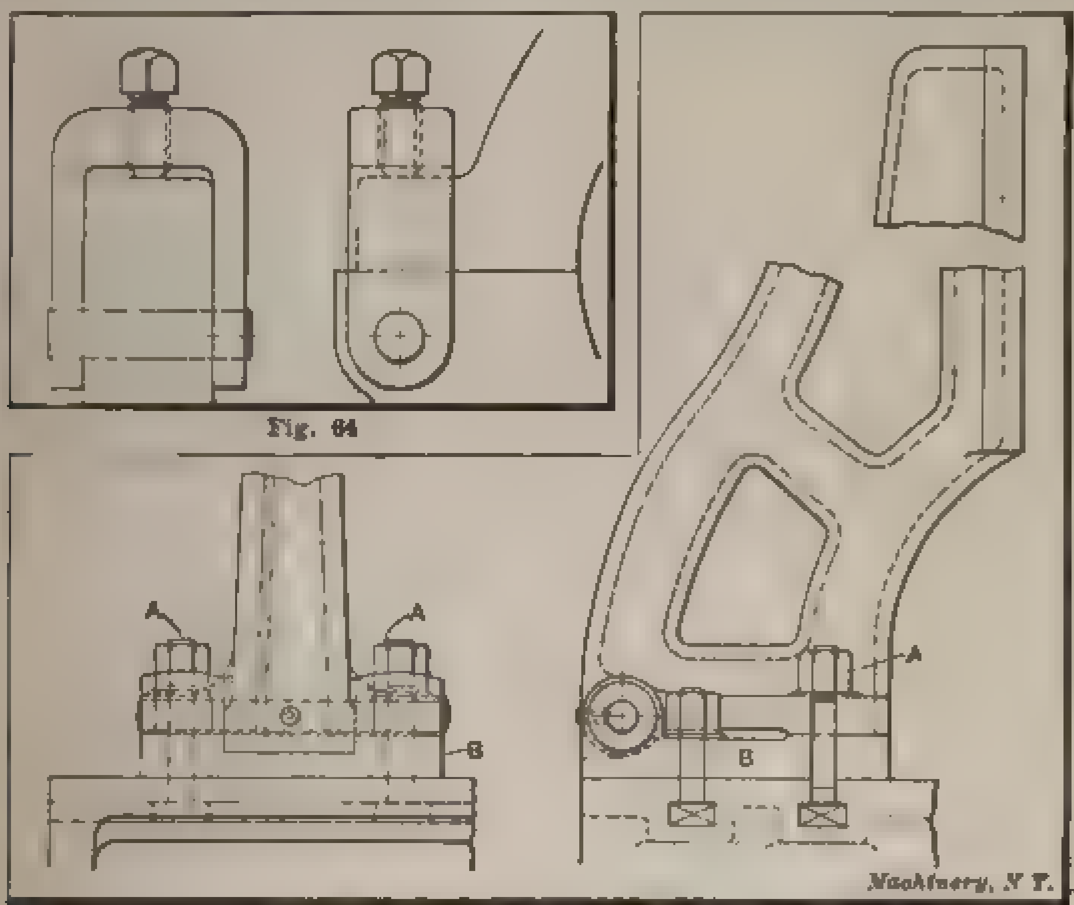


Fig. 64

Fig. 65. Clamping Device for a Bracket

bolt is slid into a slot to encounter a projection on the cone pulley. The pin may also be pushed endwise into a hole, the relative positions of in- and out-of-gear being controlled by a spring. This kind of device is also employed to lock the pulleys of grinding heads when dead-center work is being done. Fig. 66 represents a lock adopted on a high-speed lathe, the locking bolt being tapered to fit in the slot in the adjacent gear, the object being to prevent back-lash. A typical positive lock is shown in Fig. 67, this example being the pin for securing the eccentric spindle of a back-gear. The pin may be straight or parallel, as shown, but more frequently it is tapered. Slides or other parts are frequently locked by tapered pins.

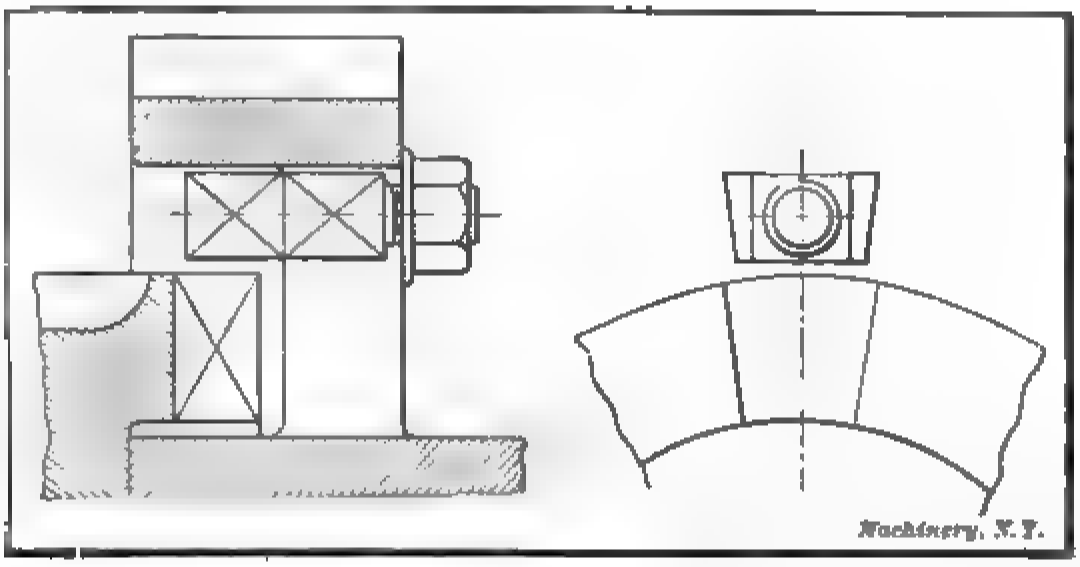


Fig. 66. Locking Pin for Lathe-head Gears

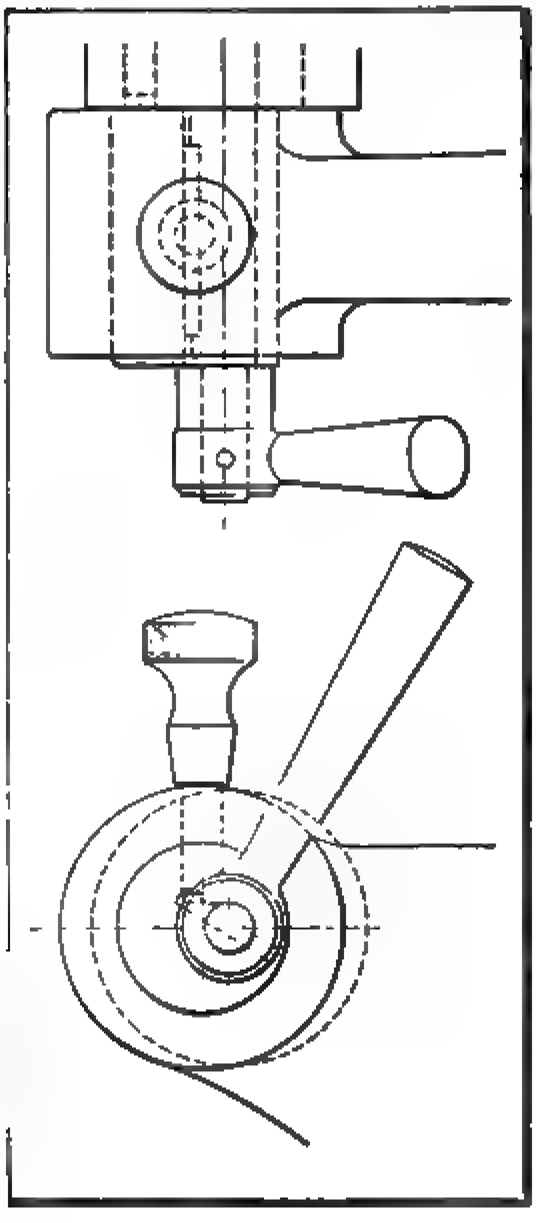


Fig. 67. Eccentric Spindle Locking Pin

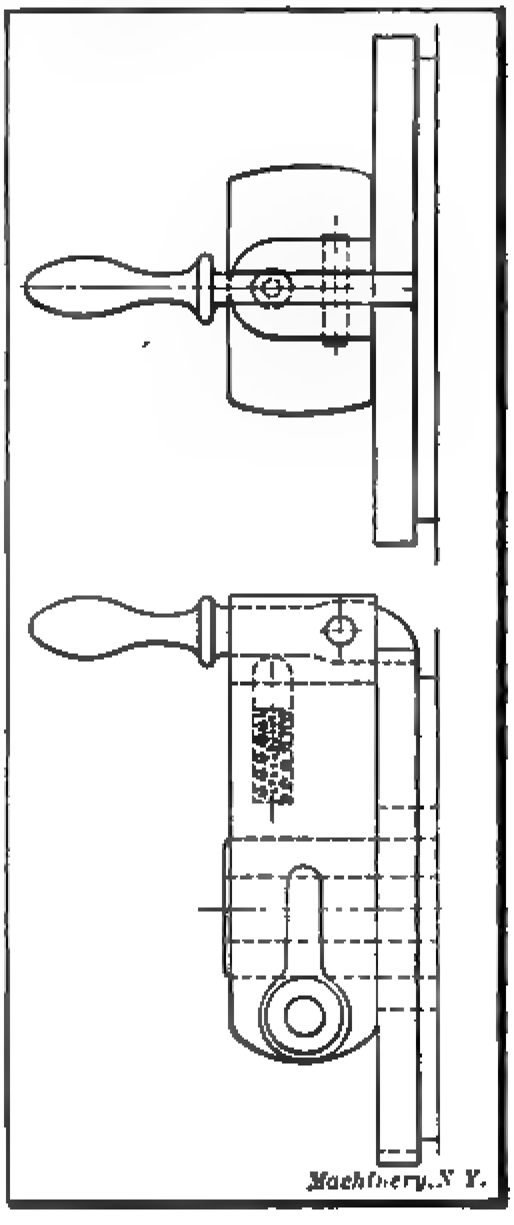


Fig. 68. Locking Arrangement for Indexing Lever

Fig. 69 is a locking device employed on the open-spindle turret lathes of Messrs. John Lang & Sons, to hold the spindle while the chuck on the nose is being tightened or loosened with a spanner. When the lock is thrown downward, the spindle is free to rotate. Two other positive locks are illustrated in Figs. 70 and 73, one for a turret lathe of the type used largely in England, the other for a central-hole type of

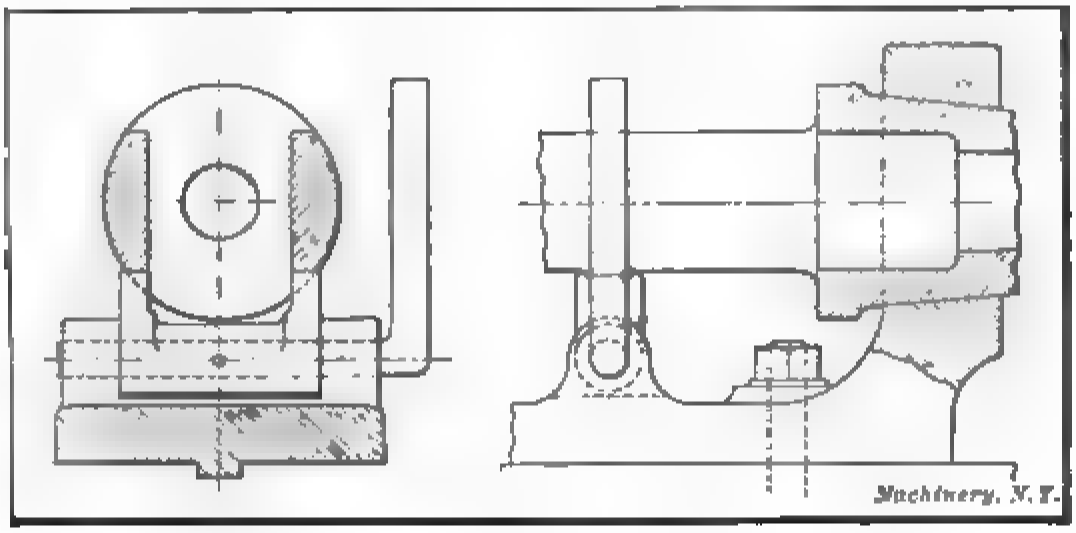


Fig. 69. Lock for Open Spindle of John Lang & Sons Turret Lathe

turret. In both cases a tapered part enters slots in the periphery of the indexing disks. The wedge strip beside the plunger in Fig. 73 takes up play due to wear.

Positive locks are also seen in Figs. 68 and 72. In Fig. 68 a disk on the body of a sleeve has notches, into any one of which the pivoted catch drops, under the action of a coiled spring, thus holding the sleeve

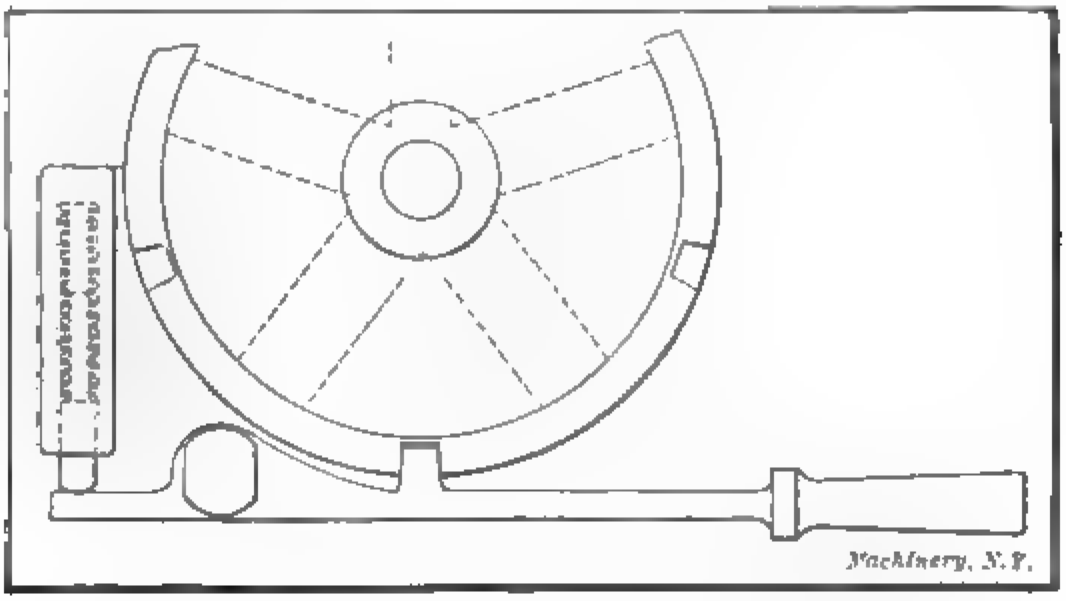


Fig. 70. Locking Turret with External Lever

in one position. Fig. 72 shows a quick-withdrawing device for screw-cutting; when the catch *A* drops into engagement with the toothed disk *B* the rotation of the latter has the effect of turning the quick-pitched screw *C*. The spring plunger *D* in the lever which carries *A*, lo the latter in either the "in" or "out" position, according to wheth

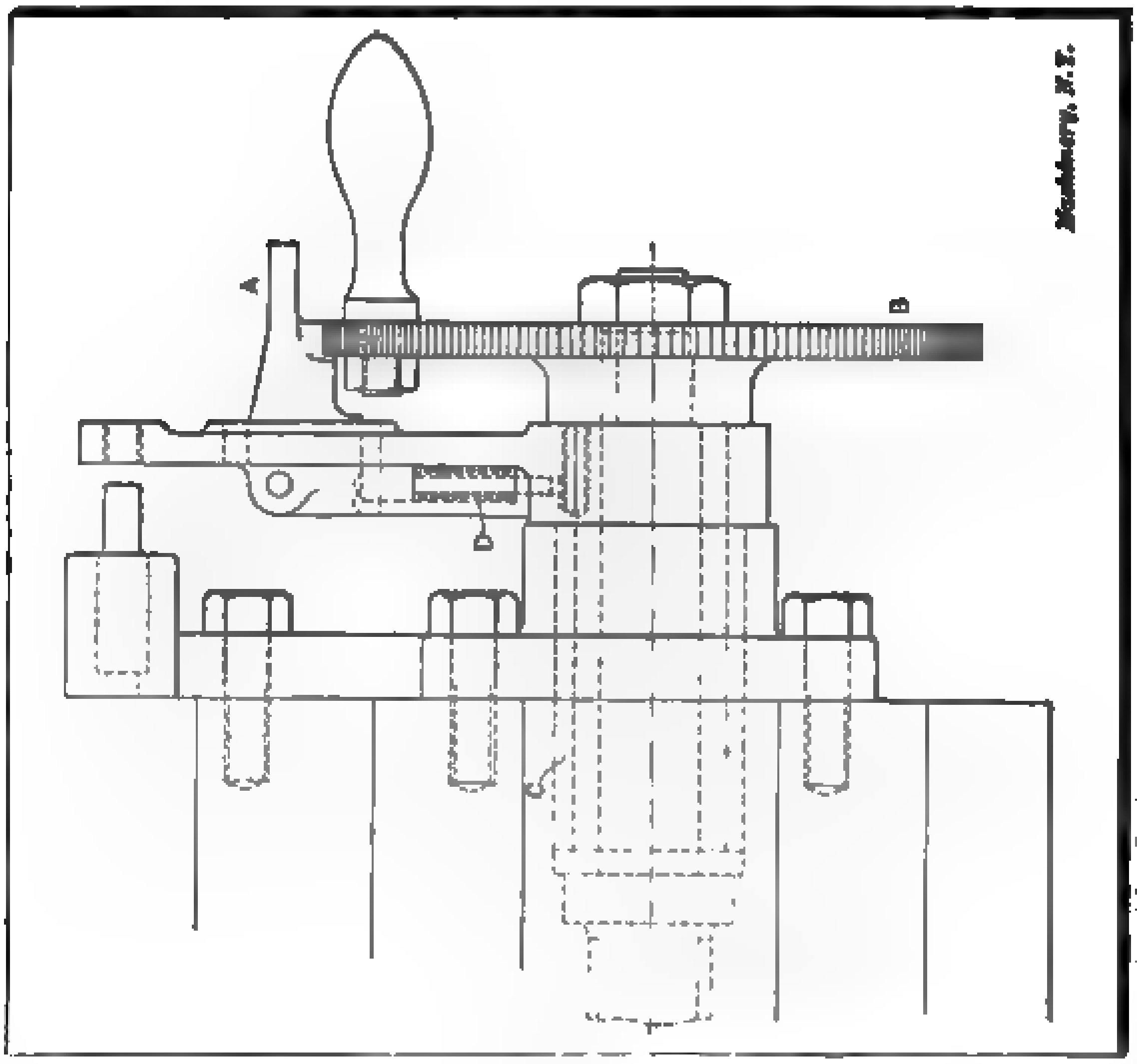


Fig. 72. Locking Arrangement for Quick Withdrawal Device on Threading Lathe

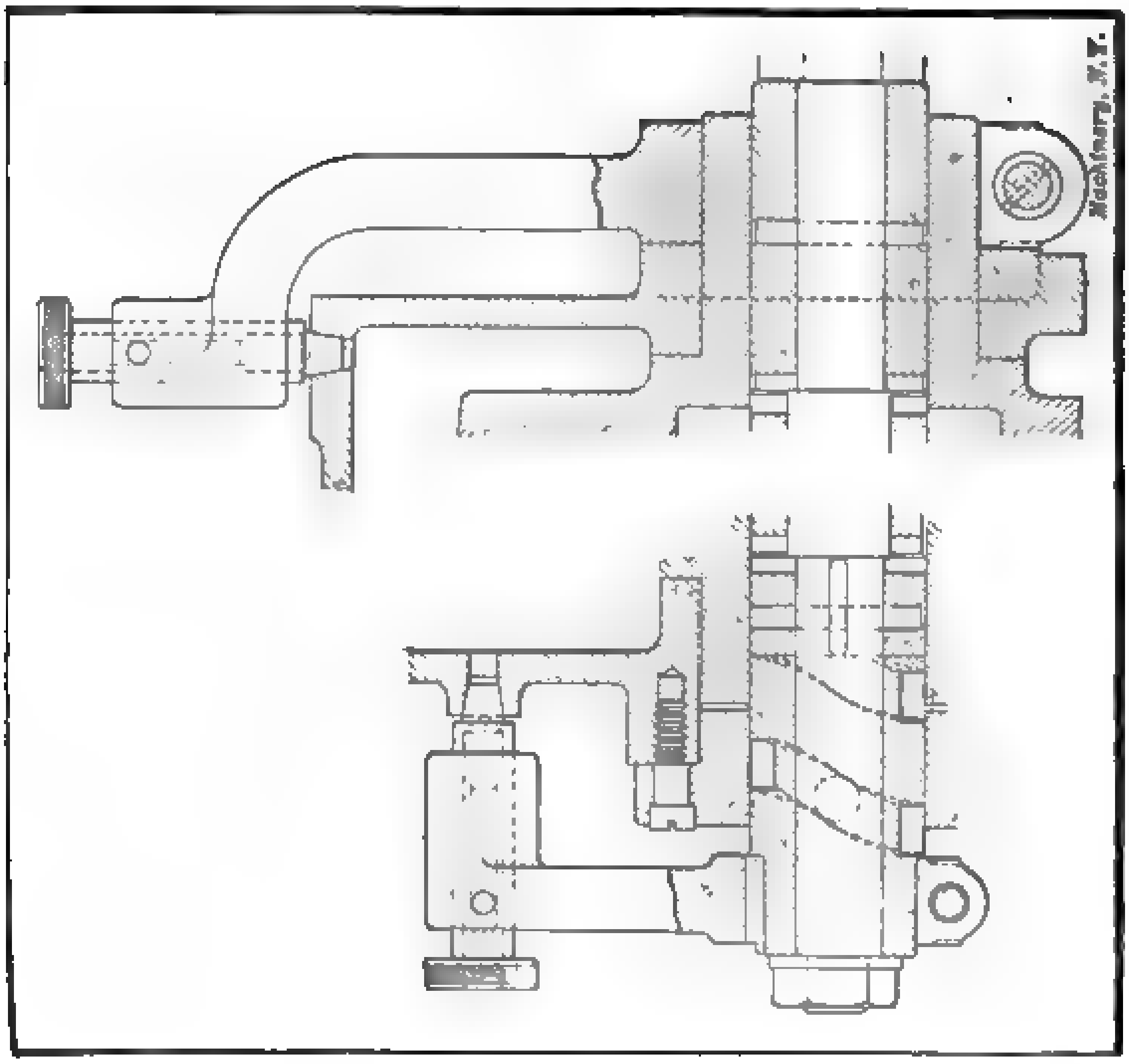


Fig. 71. Locking Plungers with Knobs for Withdrawal

plunger point slips into either the one or the other of the countersinks in the inner end of *A*.

The spring plunger is a familiar locking device, and is found in varied forms, usually embodying a pointed or tapered plunger which obviates back-lash. A common instance is that shown in Fig. 74 used

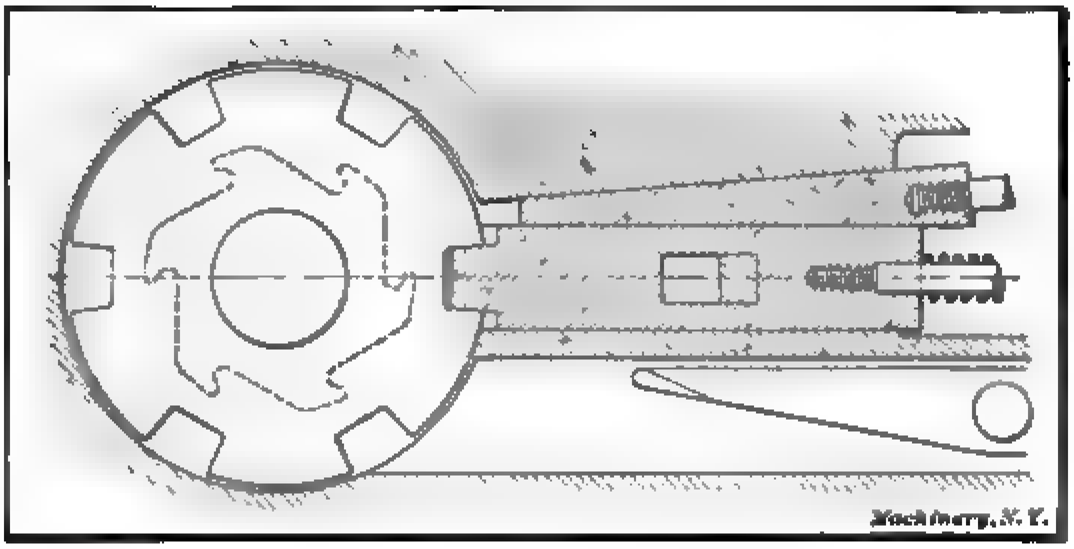


Fig. 73. Plunger Lock for Turret

for a speed- or feed-change lever. The plunger is contained within the handle, and its point slips into any one of the countersinks in the quadrant. The arrangement may also be as in Fig. 71, with a pull-back device for each plunger, as the latter in this case enter more deeply

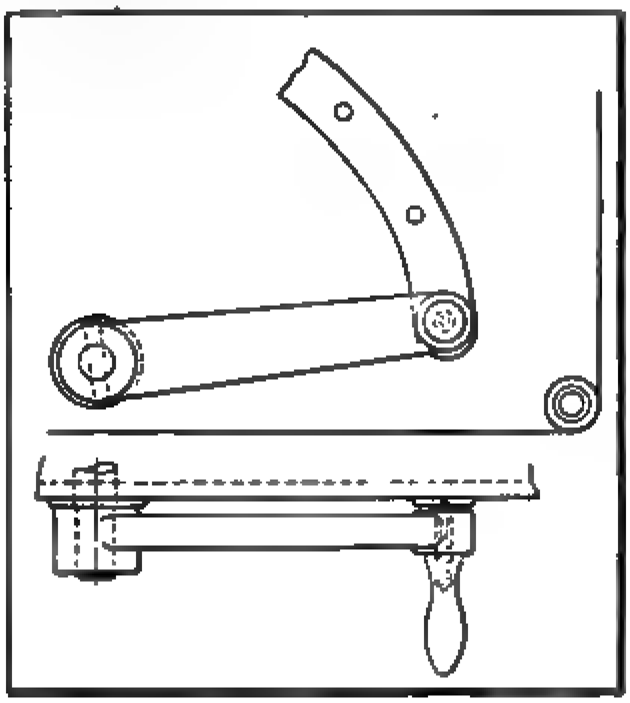


Fig. 74. Common Type of Spring Plunger for Locking Lever

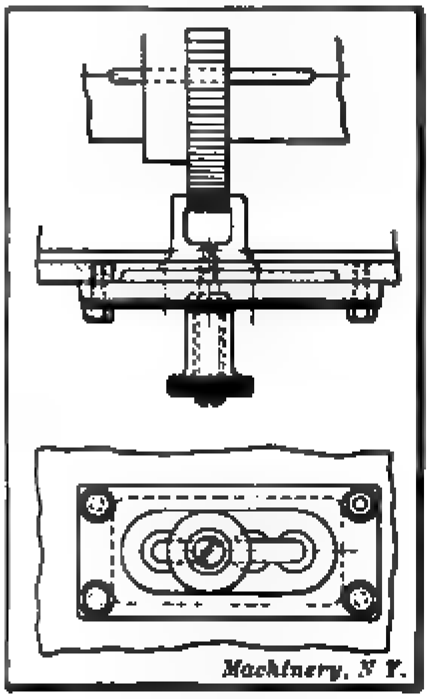


Fig. 75. Plunger Locking Arrangement for Gear Box

into their locking holes. An alternative construction is shown in Fig. 75, where the block which moves or slides the spur gears endwise is locked by a tapered sleeve entering any one of four tapered recesses in the locking plate. A spring inside the sleeve keeps it in position. Fig. 76 illustrates another method of withdrawing a plunger, this method being used on the familiar Hendey-Norton change-gear device, in which

the act of grasping the handle firmly withdraws the plunger, ready for the movement to another hole. Still another method, employed on a milling machine dividing head is represented in Fig. 79; the locking plunger in this example is pulled back by a rack and pinion device, and

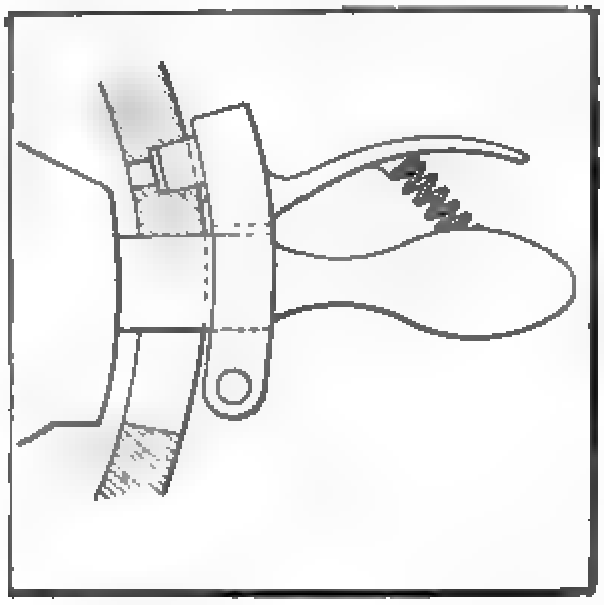


Fig. 76. Withdrawing and Locking Device on Change-gear Box

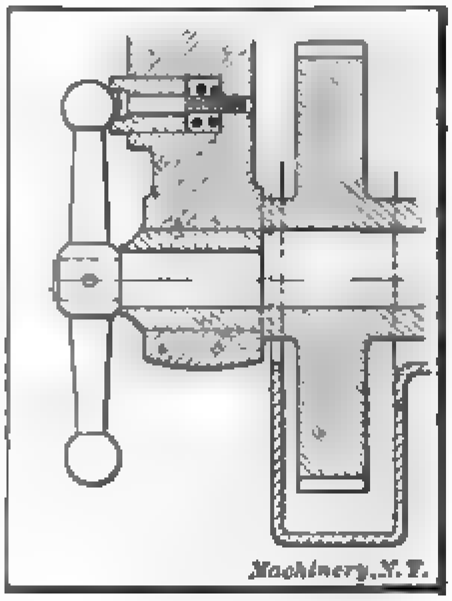


Fig. 77. Spring Lock for Back-gear Lever

the pinion sleeve is itself locked by drawing it backward until the pin near its end slips into the slot in a bushing as shown.

Fig. 78 shows a different construction, also for a dividing head, the plunger *A* has only a pull-back action, without a positive lock, while the other plunger *B* is provided with a pin which slips into a sort of

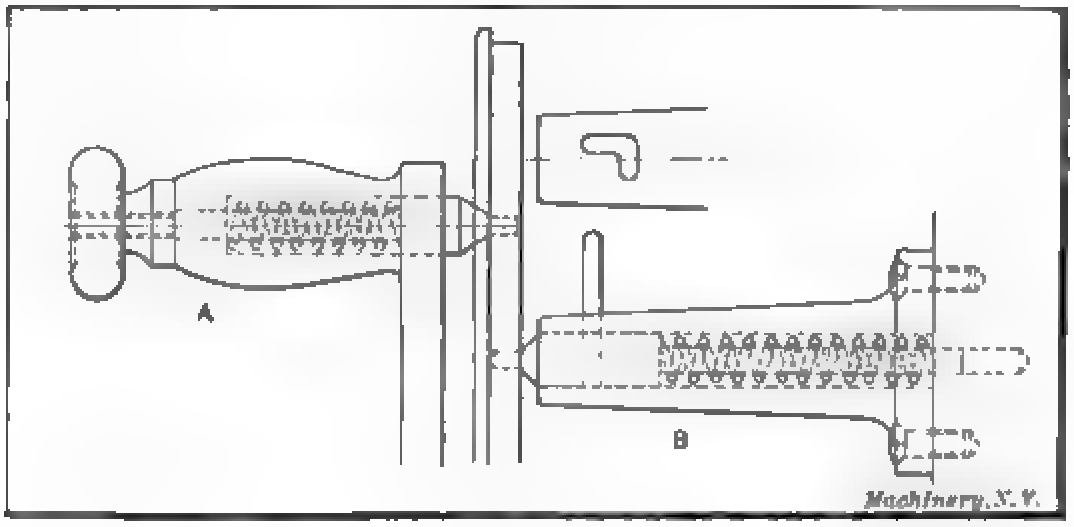


Fig. 78. Locking Plungers for Index Plate and Lever

bayonet catch, and prevents the plunger from moving forward under the action of the spring. The locking plunger in Fig. 80 (for coupling in the back-gears of a vertical milling machine), is held out of position by the pin *A*, but a quarter turn of the plunger allows this pin to slip into a groove inside the bore and thus let the plunger into any one of the holes in the disk below. Finally, the Brown and Sharpe back-gear lock, Fig. 77, represents an ingenious method of retaining automatically the ball ends of a lever in position

The succeeding illustrations are those of friction locking devices.

Fig. 81 might be classed as a clamping device, but as its only purpose is to allow locking in different positions, it should logically be classed in the latter category. The split handle or lever is employed

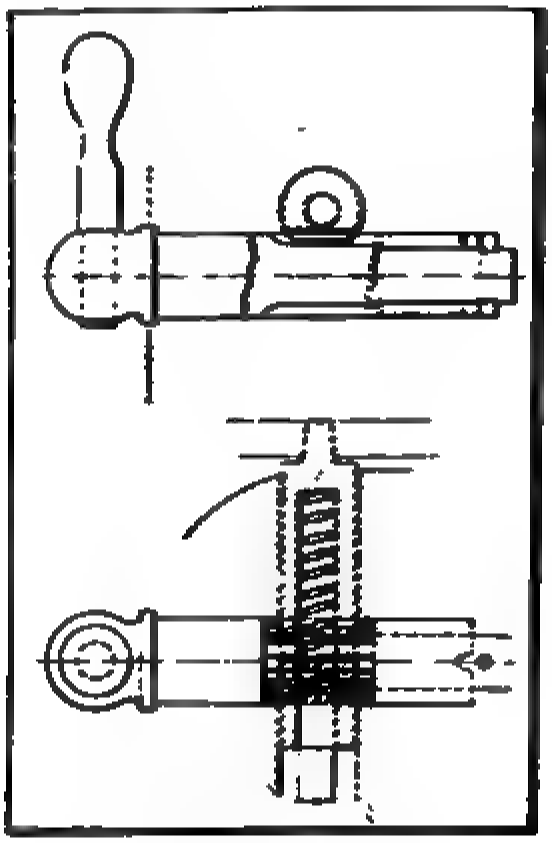


Fig. 79. Withdrawing and Locking Device for Spring Plunger

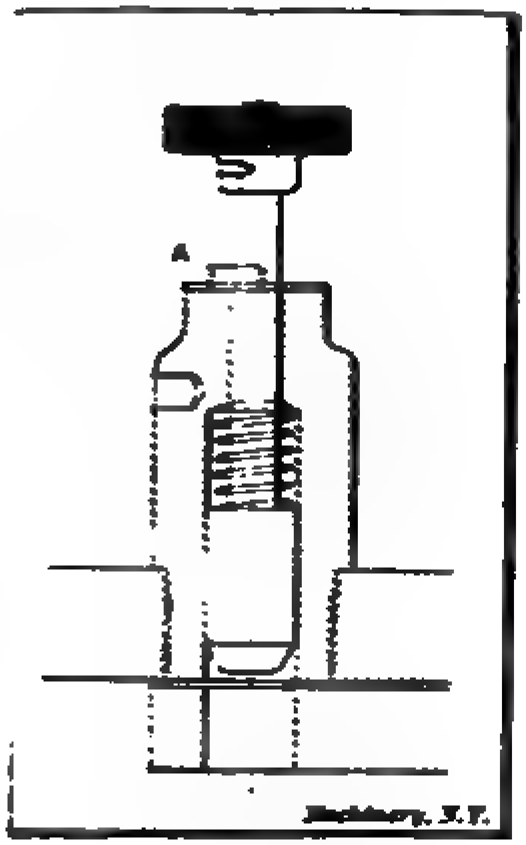


Fig. 80. Locking Plunger with Locking Pin

to work the cross-slide of a turret lathe. In order that the operator may have the handle in the most convenient and least fatiguing position, it is adjustable around the pin on which it is mounted, by

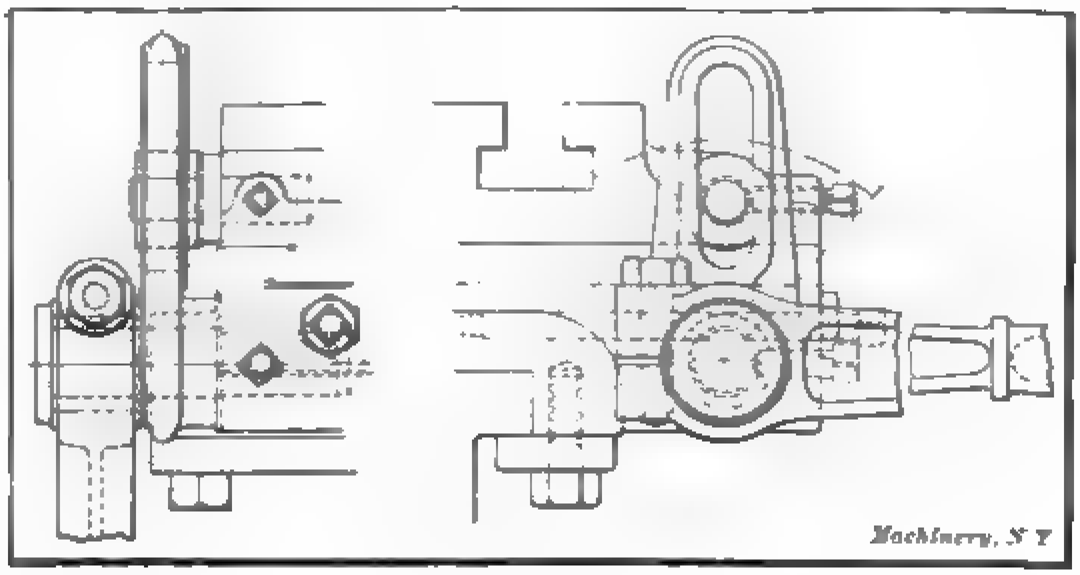


Fig. 81. Cross-slide Lever with Split Hub for Locking in Various Positions

simply loosening the binding screw. An alternative method is to taper the inside of the lever, as in Fig. 82, to match the outside of the slotted levers shown, and force the two together by a nut. This constitutes a friction clutch, and is an idea that is found in many locking devices, especially for locking gears and other parts together tem-

porarily, and for micrometer and similar devices. Other arrangements for micrometer dials are shown in Figs. 83 and 84, for locking the dials at zero when desired. Fig. 83 has a small bolt tightened by a knurled-head nut, the head of the bolt lying in a circular T-slot in

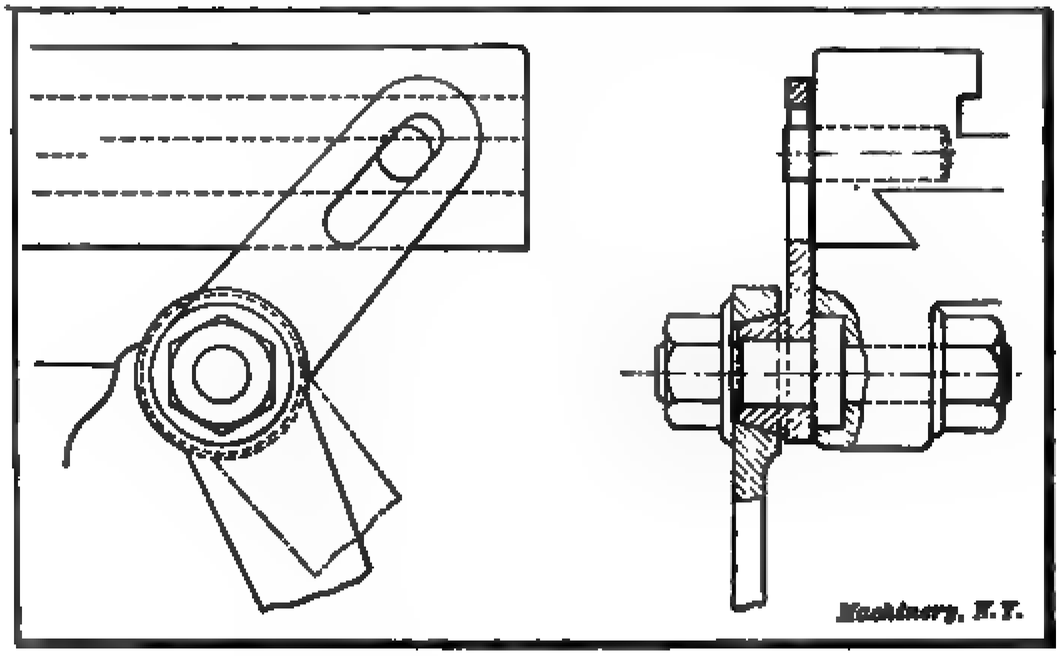


Fig. 82. Cross-slide Lever with Friction Lock

the dial. When the nut is screwed up, the dial is locked to the handwheel and turns with it. In Fig. 84 the point of the central threaded plunger forces a small block outward against the bore of the dial, and locks the latter.

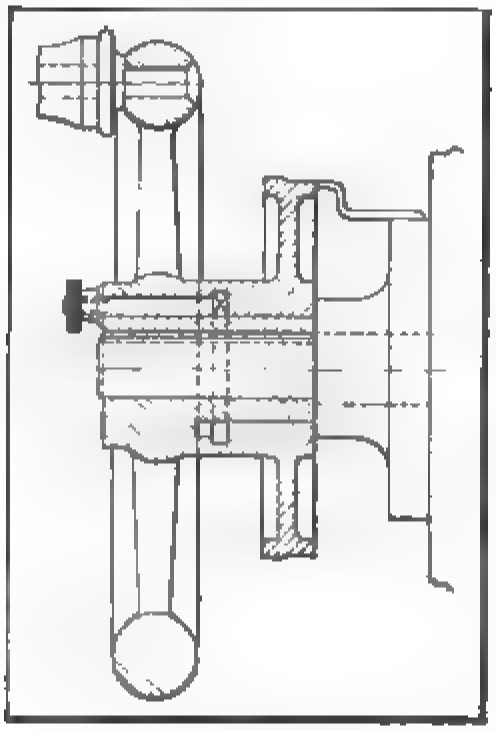


Fig. 83. T-bolt Friction Lock for Micrometer Dial

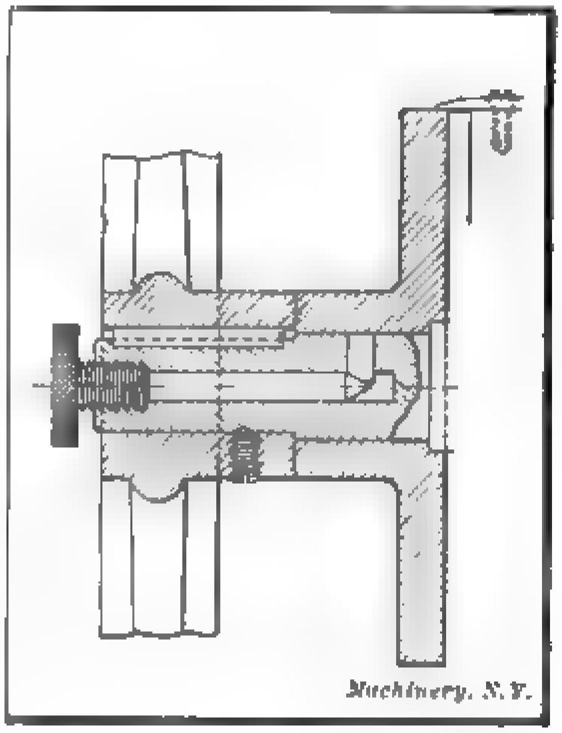


Fig. 84. Pin Friction Lock for Micrometer Dial

Ratchets are occasionally utilized for locking purposes, one instance being in wire-feeds, where the feeding dog is held on its supporting rod by a pawl entering into the teeth of the ratchet bar.

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BOLT, NUT AND RIVET FORGING

By DOUGLAS T. HAMILTON

CONTENTS

'ustrial Press, Publishers of MACHINERY,
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CHAPTER I

BOLT HEADING MACHINES

The bolt and nut industry in America started in a very small way in Marion, Conn., in 1818. In that year Micah Rugg, a country blacksmith, made bolts by the forging process. The first machine used for this purpose was a device known as a heading block, which was operated by a foot treadle and a connecting lever. The connecting lever held the blank while it was being driven down into the impression in the heading block by a hammer. The square iron from which the bolt was made was first rounded, so that it could be admitted into the block. At first Rugg only made bolts to order, and charged at the rate of sixteen cents a piece. This industry developed very slowly until 1839, when Rugg went into partnership with Martin Barnes, together they built the first exclusive bolt and nut factory in the United States in Marion, Conn. The bolt and nut industry was started in England in 1838 by Thomas Oliver, of Darlston, Staffordshire. His machine was built on a somewhat different plan from that of Rugg's, but no doubt was a further development of the first machine; Oliver's machine was known as the "English Oliver."

As is generally the case with a new industry, the methods and machines used were very carefully guarded from the public, and this characteristic seems to have followed this industry down to the present time, judging by the scarcity of information available on the subject. Some idea of the methods which were at first employed to retain all information in the factory in which it was originated is well brought out by the following instance: In 1842, when the industry was beginning to be generally known, it is stated that a Mr. Clark, who at that time owned a bolt and nut factory in New England, and had devised a special machine for use in this manufacture, had his forging machine located in a room separated from the furnaces by a thick wall. A hole was cut through this wall, and the man who operated the machine received the heated bars from the furnace through the small hole in the wall. The only person who ever got a glimpse of the machine was the operator. The forge man was not permitted to enter the room.

Machine forging, as we know it to-day, is of wide application, embracing a large number of machines and processes that apply, in a measure, to almost any manufacturing plant. Machine parts hitherto made from castings are now made much more economically by the use of the drop-hammer or forging machine, and give much more satisfactory service.

Types of Machines

Upsetting and heading machines are divided into two gen[illegible] namely, stop-motion and continuous-motion headers. T[illegible]

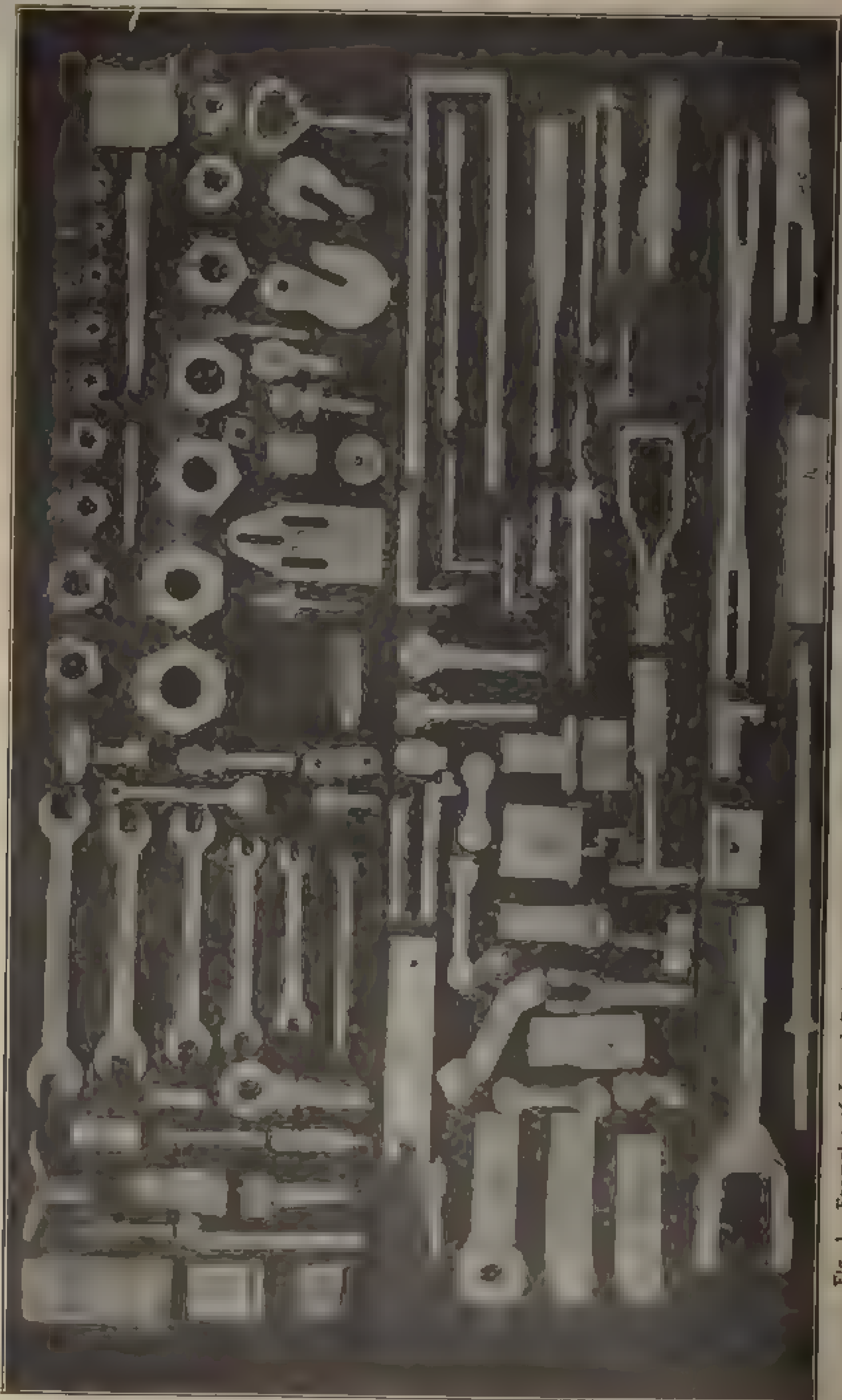


Fig. 1. Examples of Forged Parts produced in the Collinwood Shops of the L S & M S Railway on Ajax Forging Machines

headers have the greatest range, and are primarily used for heading bolts and for all kinds of upset forgings. The continuous-motion headers are used only for heading rivets, carriage bolts and short lengths of hexagon- and square-head machine bolts; they produce these parts at a much faster rate than is possible with a stop-motion header, but their range of work is limited. The universal practice is to shear the bars cold when working a stop-motion header, and only in special cases, when the shank of the headed piece is very short, is the side shear used.

Rivets, etc., forged in the continuous-motion header, are made by the process known as "off the bar;" that is, a bar is heated for a distance of approximately four feet, and is then pushed into the machine where the moving die acts as a shear and cuts off the blank. The

Fig. 2. Ajax Bolt Heading Machine suitable for all Types of Machine Bolts and Upset Forgings

latter is immediately gripped against the stationary die, whereupon it is headed and ejected. This whole cycle of movements is accomplished in one revolution of the flywheel.

Operation of Plain Bolt and Rivet Machines

Briefly stated, a plain bolt and rivet machine comprises two gripping dies, one movable and the other stationary, and a ram which carries the heading tool. The heated bar is placed in the impression in the stationary gripping die, and against the gage stop; the machine is then operated by pressing down the foot treadle shown in front of the machine in Fig. 2. As already mentioned, the stock is generally cut to the desired length before heading on this type of machine, especially when it is long enough to be conveniently gripped with the tongs; but it can be headed first [illegible] cut off to the

desired length in the side shear. It is also possible, in some makes of machines, to insert a cutting tool to cut off the blank before heading, when the work is not greater in length than the capacity of the machine.

There are several methods used in making bolts and rivets in a regular forging machine. In Fig. 3 is shown a diagrammatical view

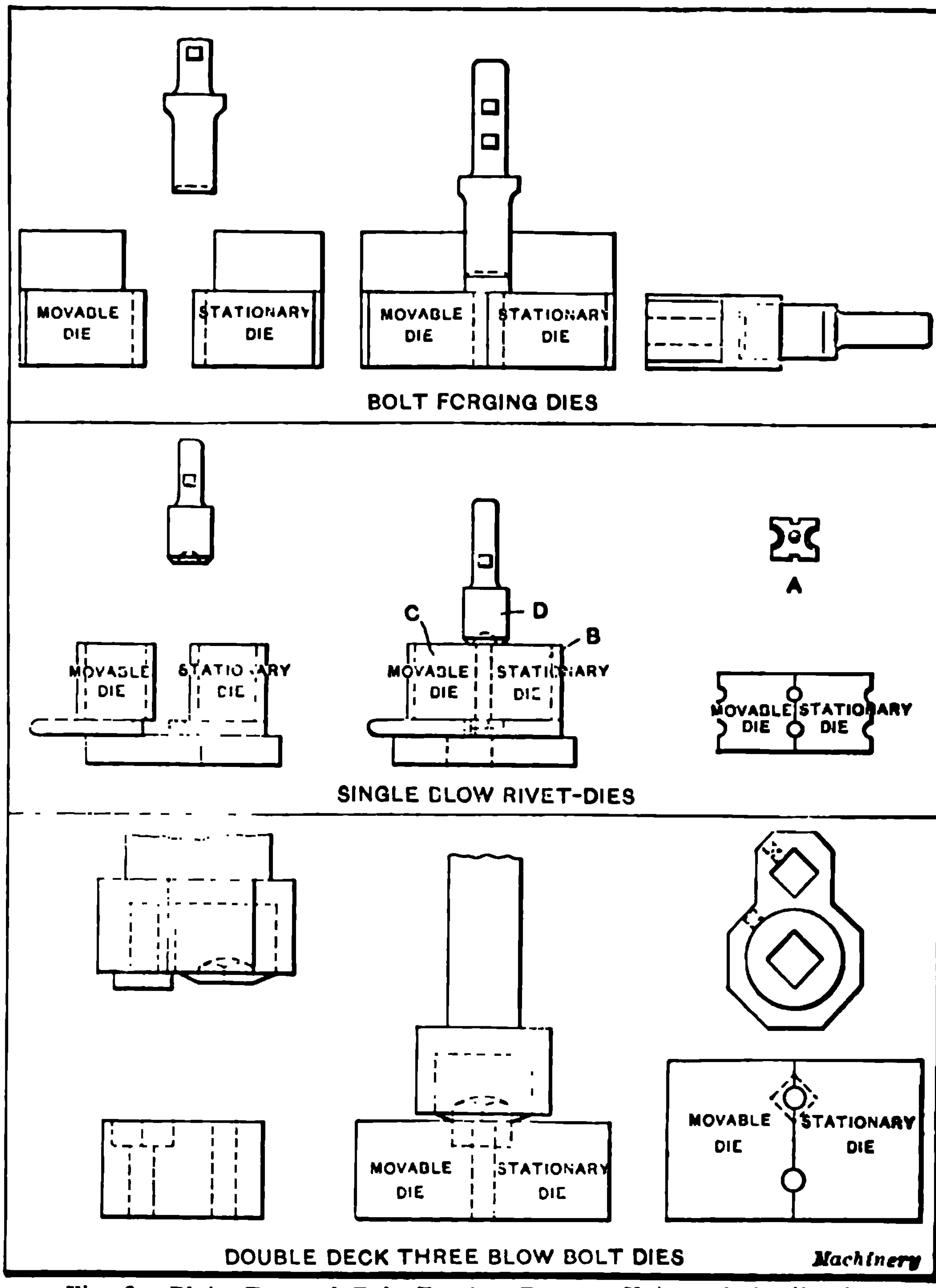


Fig. 3. Plain Type of Bolt Forging Dies of Universal Application.
Fig. 4. Single-blow Rivet Dies. Fig. 5. Double-deck Three-blow Dies

of a set of forging dies which have a very wide range of application. In this type of dies the head on the bolt is formed by rotating the bar between the gripping dies after each blow of the plunger. For a square-headed bolt, the bar is turned twice through a space of 90 degrees, and is generally given two or more blows in each position. A hexagon-head bolt usually requires at least six blows to complete one

Fig. 6. First Step in the Production of Bolt Heads in Plain Forging Dies of the Type shown in Fig. 3

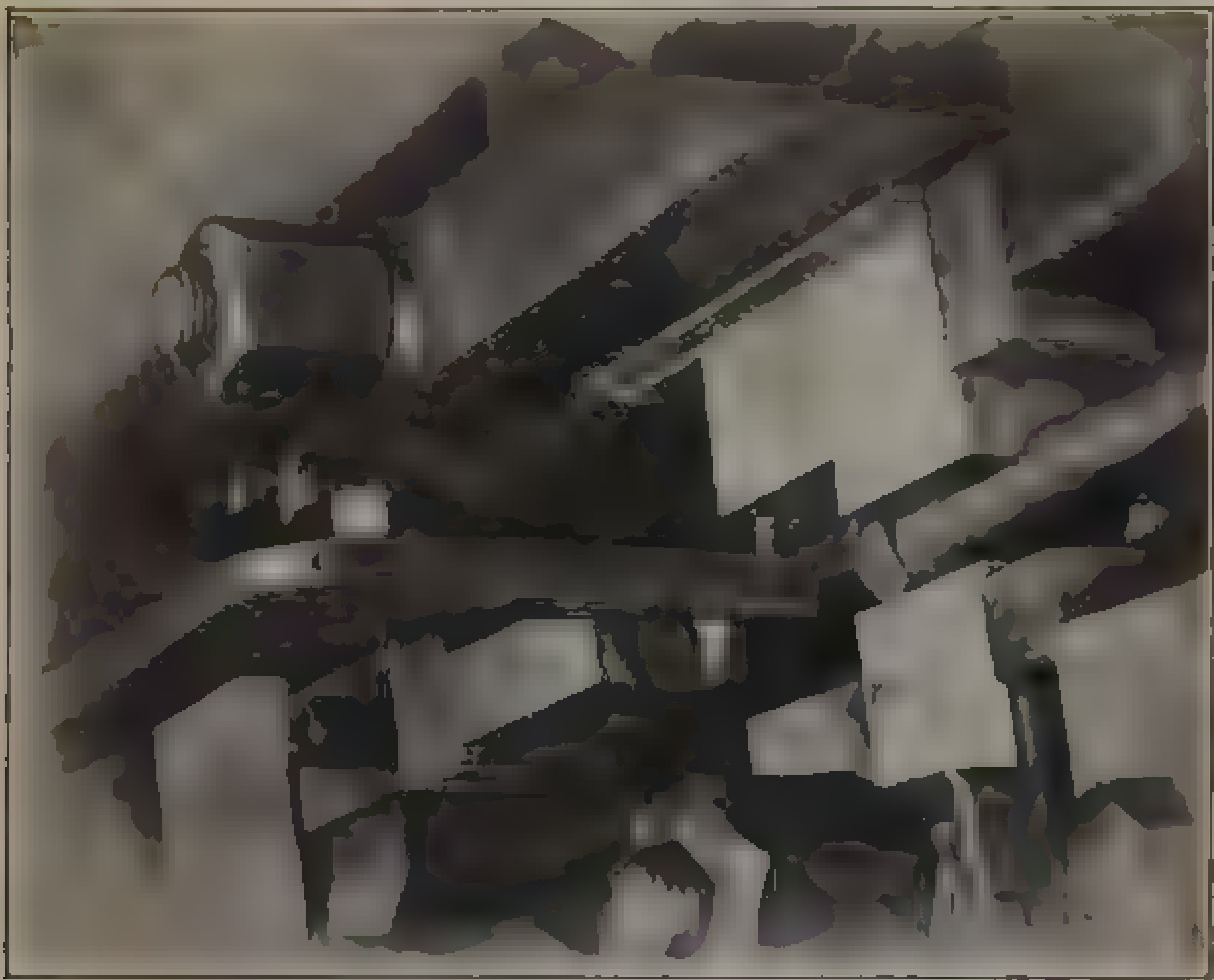


Fig. 7. Second Step in the Production of Bolt Heads

bolt, and the shape of the head depends to a large extent on the skill of the operator. The wide range of work, however, which can be handled in dies of this type, makes them of almost universal application, especially in a railroad shop.

Fig. 4 shows a set of single-blow rivet dies which are used in a continuous-motion rivet header, and illustrates how these dies are operated in the making of a rivet in one blow. The heated stock is fed in and cut off to the exact length by a shear *A*; it is gripped

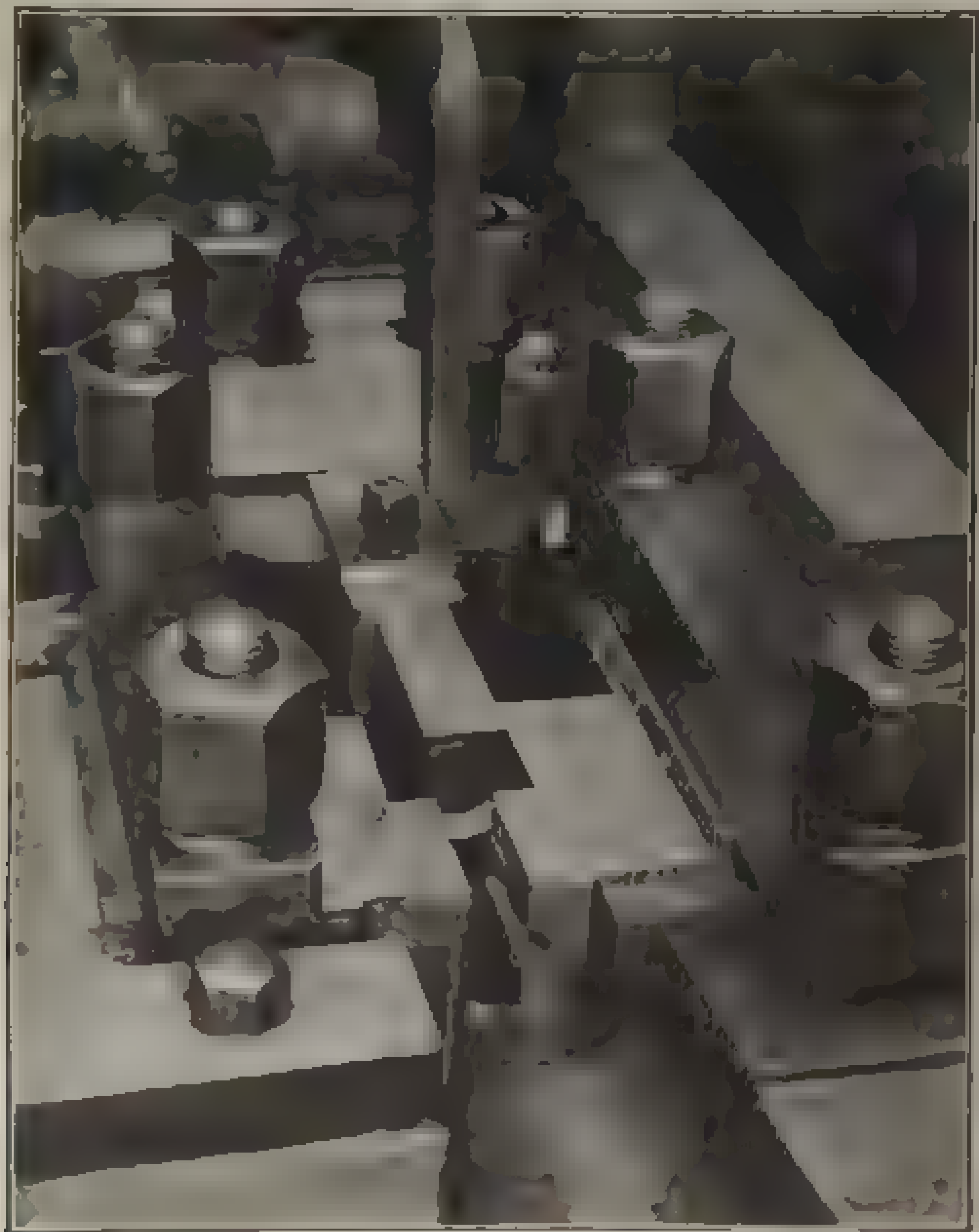


Fig. 8. Third Step in the Production of Bolt Heads

between dies *B* and *C* while being cut off. Tool *D*, held in the ram of the machine, then advances, upsetting the head to the shape shown, whereupon the movable die backs out, allowing the formed rivet to drop out and the bar to be inserted to the stop, ready for the next piece. The type of bolt heading tool illustrated in Fig. 5 is known as a double-deck three-blow bolt die; its use and operation will be explained later.

Successive Steps in Heading Bolts

Figs. 6, 7 and 8 show the successive steps followed in the forging of a hexagon-head bolt in the type of bolt forging dies illustrated in Fig. 3. Bar *A*, which is heated for a portion of its length, is placed in the impression in the stationary gripping die *B*, as shown in Fig. 6, and is gaged to length by the lifting stop *C*. The machine is then operated, and the movable die *D* closes in on the bar, gripping it rigidly. The stop now rises, and, as the ram of the machine advances, the plunger *E* upsets the end of the bolt, the blocks *F* and *G* forming a flat on each side of the upset end. The operator keeps his foot on the treadle, and as the movable die backs out, he rotates the rod one-sixth of a turn. This operation is repeated until the head has been correctly formed. The operator now removes his foot from

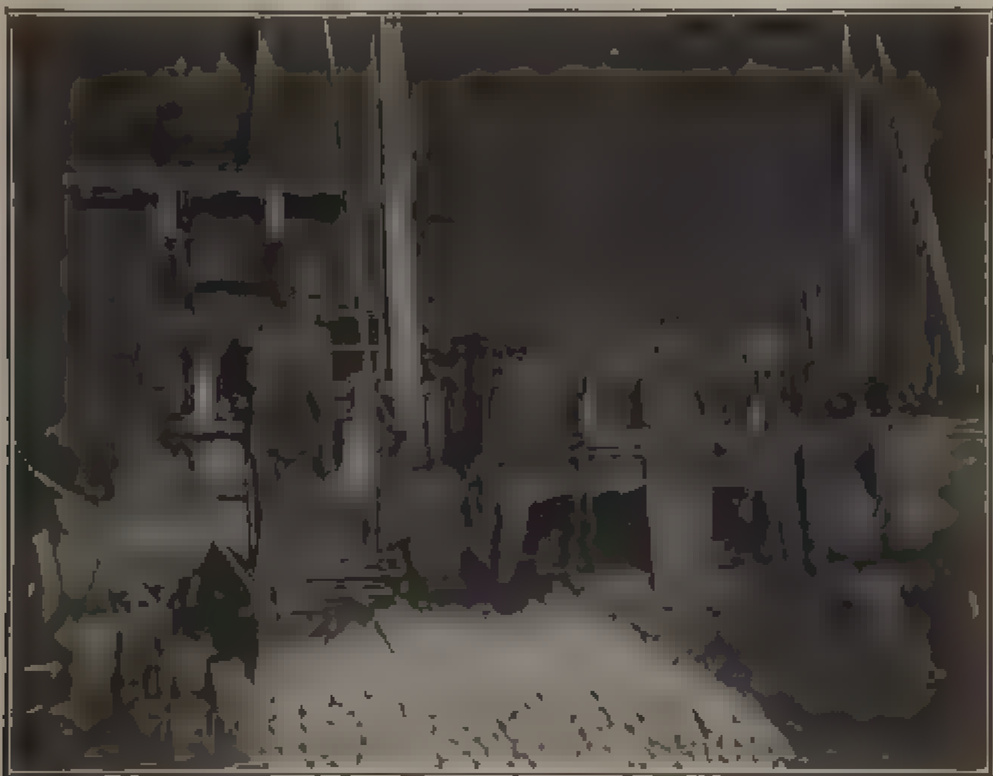


Fig. 9. Heading Bolts in a 2-inch Ajax Forging Machine in the L. S. & M. S. Railway Shops

the treadle, stopping the operation of the machine, when the dies remain in the open position, allowing him to remove the completed bolt as shown in Fig. 7. This view shows the stop down and the dies open ready for the rod to be inserted again, while Fig. 8 shows the dies open and the plunger on its return stroke.

Fig. 9 shows how the furnace and forging machine are arranged for making bolts and machine forgings in a Cleveland railroad shop. The bars in this case are long enough to be gripped with the tongs, and are therefore cut off to the desired length in a power shear before heading. From the power shear the bars are brought to the heating furnace, in the truck shown to the right in the illustration, where one end of the bars is heated to the desired temperature. This furnace is heated by oil and is placed as close to the forging machine as possible. The man who attends to the h[illegible] of the stock places

the rods in a row, and as soon as the end to be headed reaches the proper temperature, he quickly removes the heated bar and passes it to the forging machine operator, who immediately places it between the dies, operates the machine, and forms the head. In this particular example the bolt is $1\frac{1}{4}$ inch in diameter by 12 inches long, and is formed in three blows in double-deck dies of the type illustrated in Fig. 11. The dies and heading tool are kept cold by means of a constant stream of water. As soon as the bolt is headed it is thrown

Fig. 10. View looking down into the Die Space of an Ajax Bolt Forging Machine

in the truck to the left, which is used for conveying the bolts to the threading machines.

Fig. 10 shows a view looking down into the die space of the "Ajax" bolt header, from which an idea of the relation between the working members can be obtained. The back stop *A* is used for locating the bar in the correct position. This stop is sometimes used instead of the swinging stop *B*. This view also shows how the gripping dies are held in the die space; a heel plate fastened to the frame of the machine and to the movable die-slide by studs and nuts, carries set-screws which bear down on the die blocks, holding them tightly in the die space.

Types of Bolt Header Dies

Fig. 11 shows a type of bolt heading dies known as double-deck three-blow bolt dies, which are used for finishing hexagon-head bolts. The two gripping dies *A* and *B*, as a rule, are made from blocks of tire steel; each gripping die is made from three pieces to facilitate machining. The lower header punch *C* is cupped out to form a hexagon, and is held in the heading tool-holder which is attached to the ram of the machine. The upper punch *D* is held in the same manner as the lower heading punch, and forces the bolt into the hexagon impression in the dies after it has been roughly formed in the lower impression. This type of die produces a bolt free from fins and burrs, and accurate as regards size and shape. The bolt is given one blow in the lower position and then raised to the upper die impression, where it is generally given two blows.

A combination set of double-deck gripping dies for making square- and hexagon-head bolts is shown in Fig. 12. The construction of these

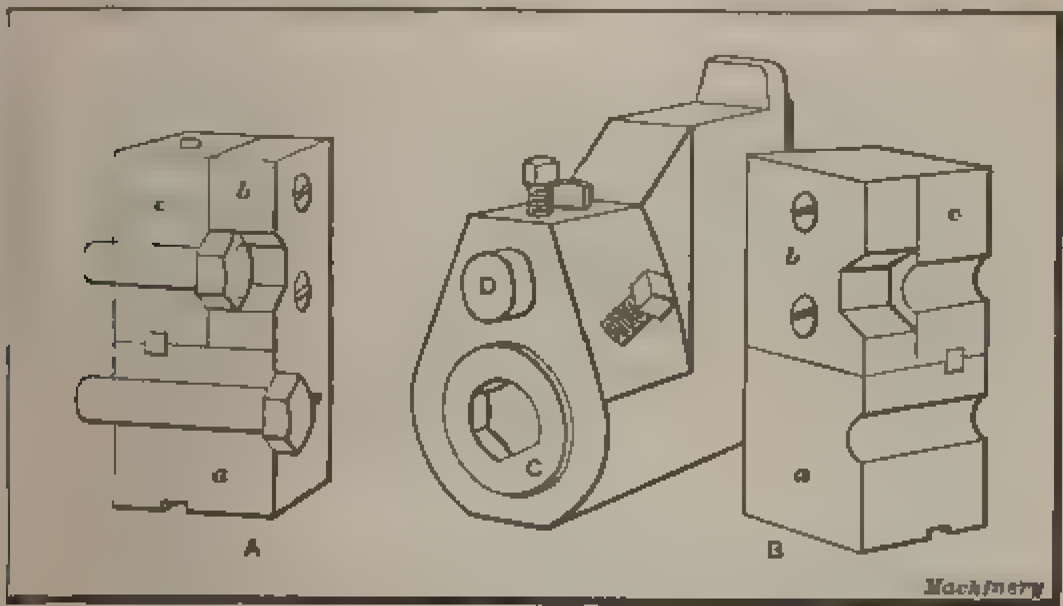


Fig. 11. Type of Double-deck Dies used in producing Bolt Heads without Fins or Burrs in Three Blows

dies is similar to that of the dies shown in Fig. 11, with the exception that these dies can be used for making both square- and hexagon-head bolts. The punches for forming the hexagon- and square-head bolts are shown at the right and left, respectively. A general idea of the class of work turned out in a bolt and rivet header may be obtained from Fig. 13.

Construction of National Wedge-grip Bolt and Rivet Header

Fig. 14 shows a view of a two-inch National wedge-grip bolt and rivet header which is used for making bolts, rivets and miscellaneous forgings. There are a number of interesting features connected with this machine, one of which is the wedge-grip and automatic relief mechanism. In [illegible] and rivet header it is necessary that the work be [illegible] impression in the gripping dies and not [illegible] Both of these dies must come

tightly together, and are made to do so by the mechanism of the machine; therefore any foreign body preventing the correct movement of these dies would cause trouble by breaking the machine, if no special means to safeguard against this were provided. Various

Fig. 12. Combination Square and Hexagon Double-deck Bolt Dies

methods have been used, however, for obviating this difficulty, one of which is the application of a shearing pin in the movable gripping die slide, which, when the foreign body is placed between the dies,

Fig. 13. Some Examples of Work turned out on National Wedge-grip Bolt and Rivet Header

is sheared off without causing any damage to the machine. Another method, which is a special feature of the National wedge-grip header, is a spring relief, which throws the entire gripping mechanism out of action should the stock or any foreign body be caught accidentally between the dies and prevent them from closing. The action of this

relief is indicated in Figs. 15 to 17. In Fig. 15 the gripping dies are shown closed and the relief mechanism does not operate. In Fig. 16, the gripping dies are shown open and the ram is at its extreme backward stroke, while in Fig. 17 the dies are open, but with the ram at the forward end of the stroke. The latter view shows what happens when a foreign body is caught between the gripping dies and prevents them from closing.

The relief mechanism consists of a spring plunger *A*, the front end of which is beveled, and which is kept in the "out" position by a coiled spring. This plunger, as indicated in Fig. 16, presses against an angular projection on the movable gripping slide. Now when a foreign body comes between the gripping dies and prevents them

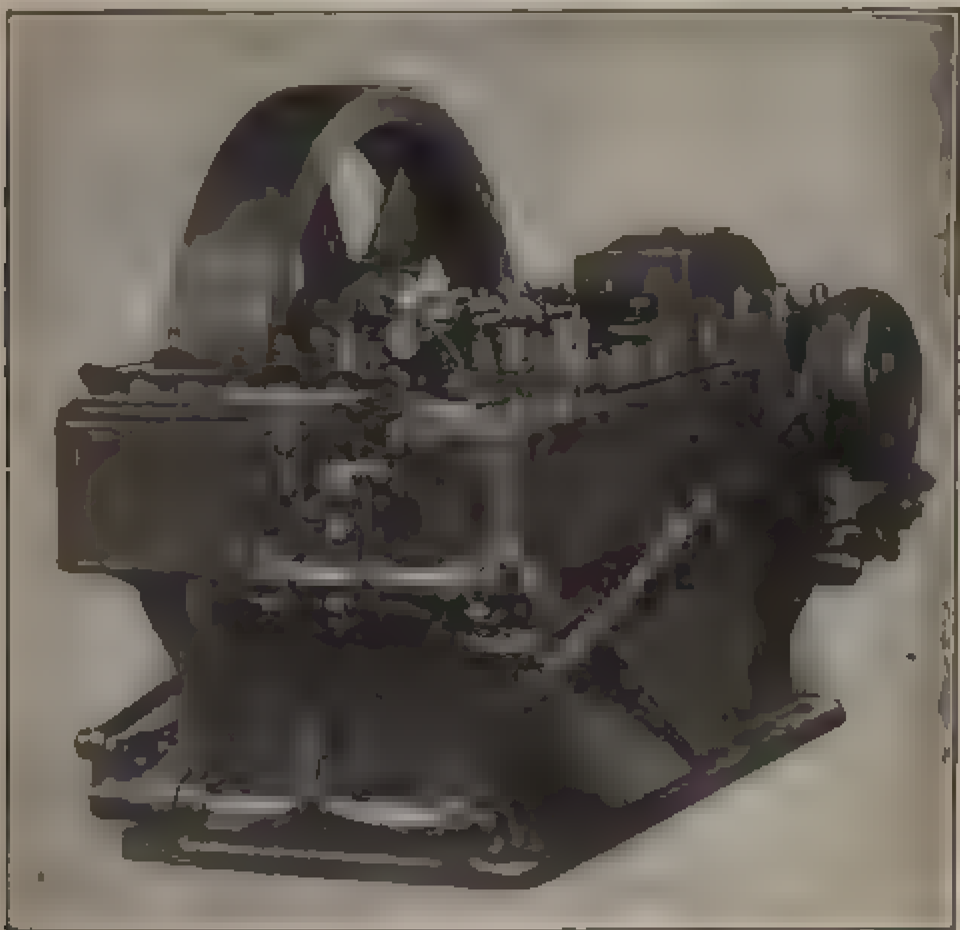
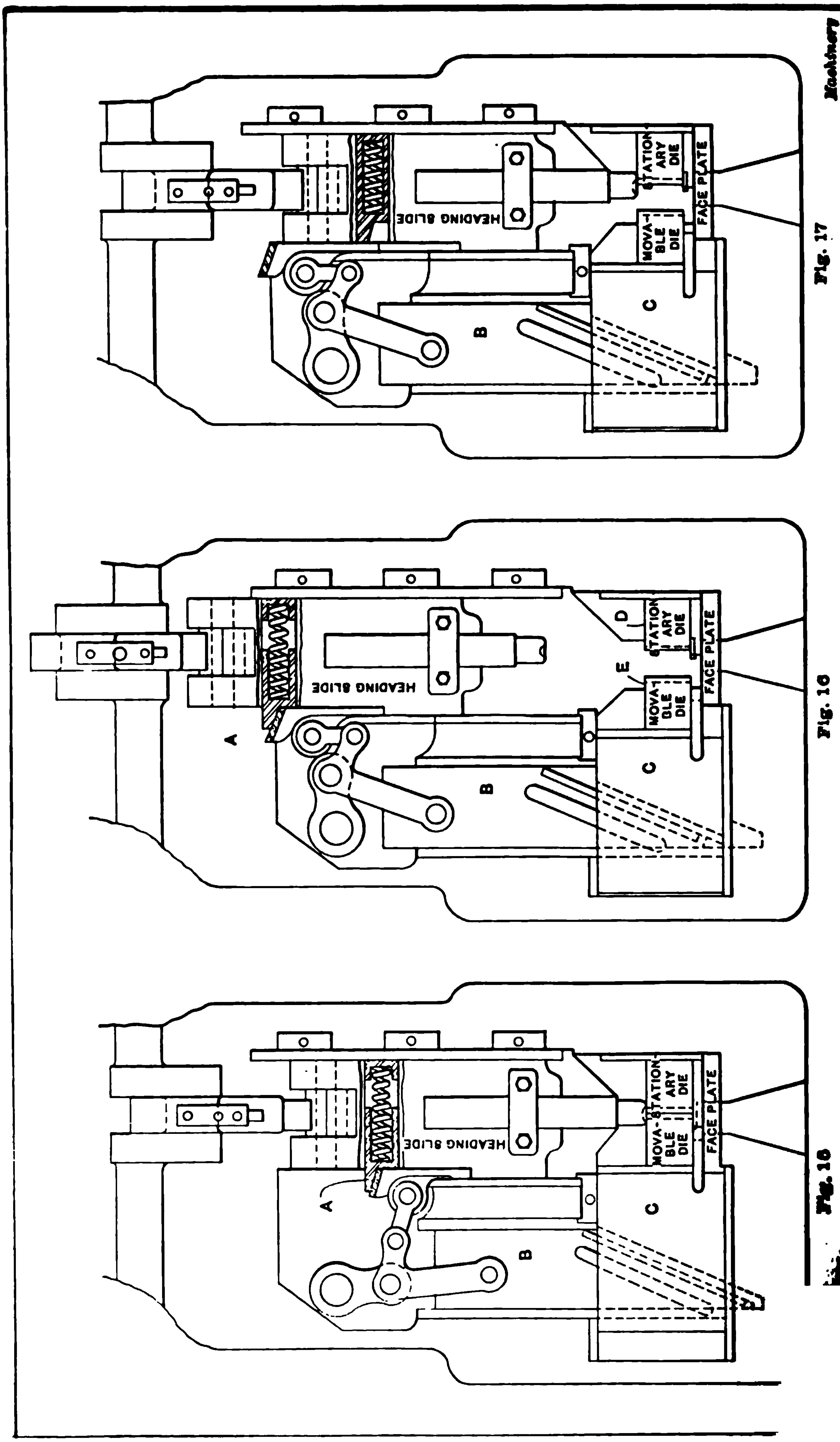


Fig. 14. Two-inch National Wedge-grip Bolt and Rivet Header

from closing, this spring plunger is forced back and the toggle joint operating the wedge gripping slide remains stationary; this allows the dies to remain open, although the ram completes its full forward travel. This relief will operate up to the time the dies are closed, but when the dies are closed, the gripping pressure is positive.

An important feature of this machine is the wedge-grip for the movable slide. This consists of a slide *B* to which the toggle lever is attached, and which is moved back and forth by the latter through the movement of the crankshaft. The forward end of slide *B* is beveled and forms [illegible] tal backing when the gripping slide *C* is in the forward [illegible] n—when the dies are closed. This means of [illegible] ring the heading operation prevents any [illegible] de and causes an even pressure



16 and 17. Diagrams illustrating Construction and Operation of National Wedge-grip Bolt and Rivet Headers

to be exerted over the entire working surface of the dies. The stationary die *D* and movable die *E* are set so that their working faces merely touch, and the rigidity of the grip prevents any spring, so that the work can be produced without fins and burrs. By not having to set the dies ahead, the pounding or battering and premature wearing out of the dies is prevented.

Fig. 18 shows more clearly how the movable and stationary dies are retained in the die space, and how they are backed up by steel liners. From an inspection of this illustration it will be seen that with this

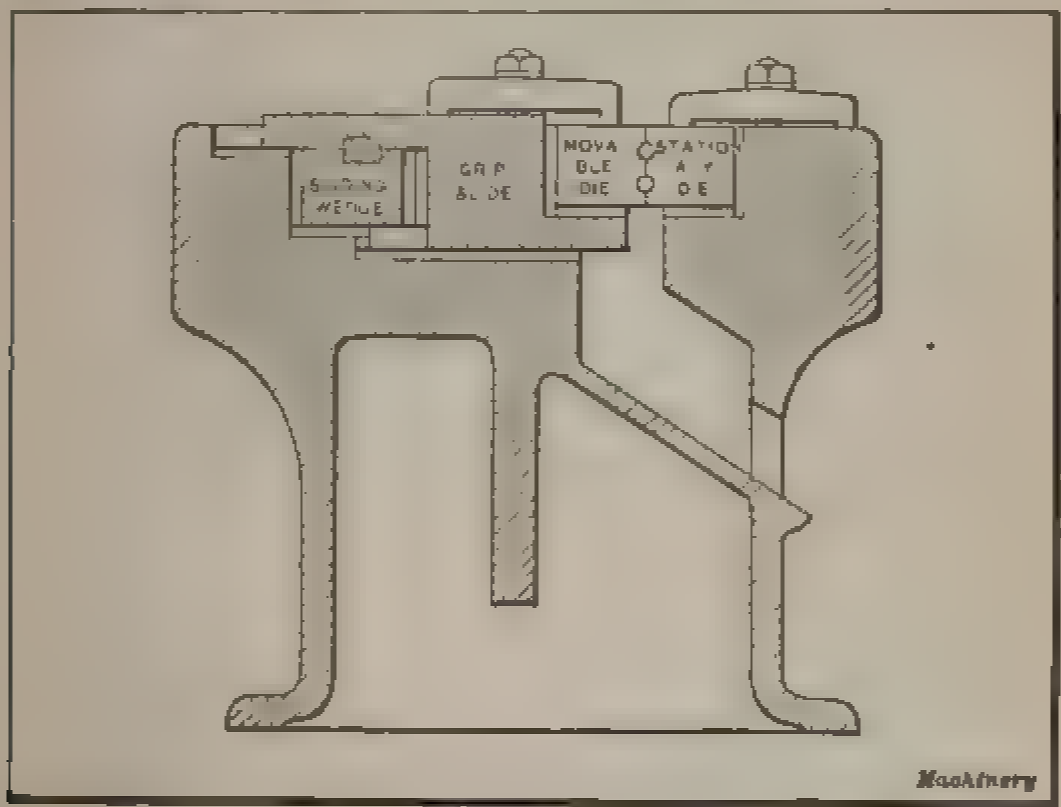


Fig. 18. Section through Die Box of the National Wedge-grip Bolt and Rivet Header

sliding wedge mechanism it is practically impossible for the dies to give or spring when in operation on the work.

Hammer Type of Bolt Header

In the type of bolt and rivet making machines so far described, the head is formed by hitting the heated bar on the end and forcing it into suitably shaped impressions in the gripping dies. In the following, attention will be given to a type of bolt heading machine in which the end of the bar is first upset and the head then formed to the desired shape by the combined action of the upsetting punch and hammer dies operating from all four sides.

In the hammer type of bolt header, shown in Figs. 19, 20 and 21, the head of the bolt is formed by an end working upsetting punch and four hammers which are operated from all four sides at right angles
e bolt. In operation, the heated blank, which has
length, is placed in a seat (when the bolt is
commodated) and between the gripping dies,
the adjustable stop *A*. Then by a move-

ment of the hand-lever *C*, the dies (one of which is shown at *B* in Fig. 21) are closed and the machine is started. The stock is not moved during the forging operation, but is kept up against the adjust-

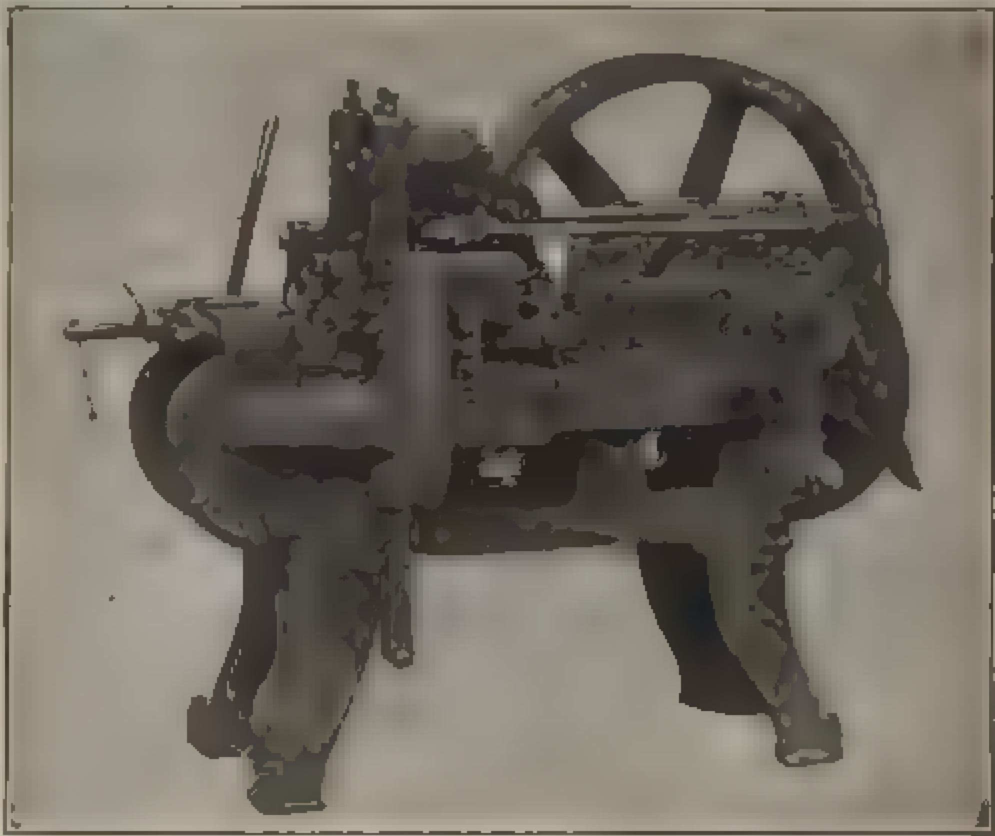


Fig. 19. Type of Hammer Header made by the National Machinery Co., Tiffin, Ohio

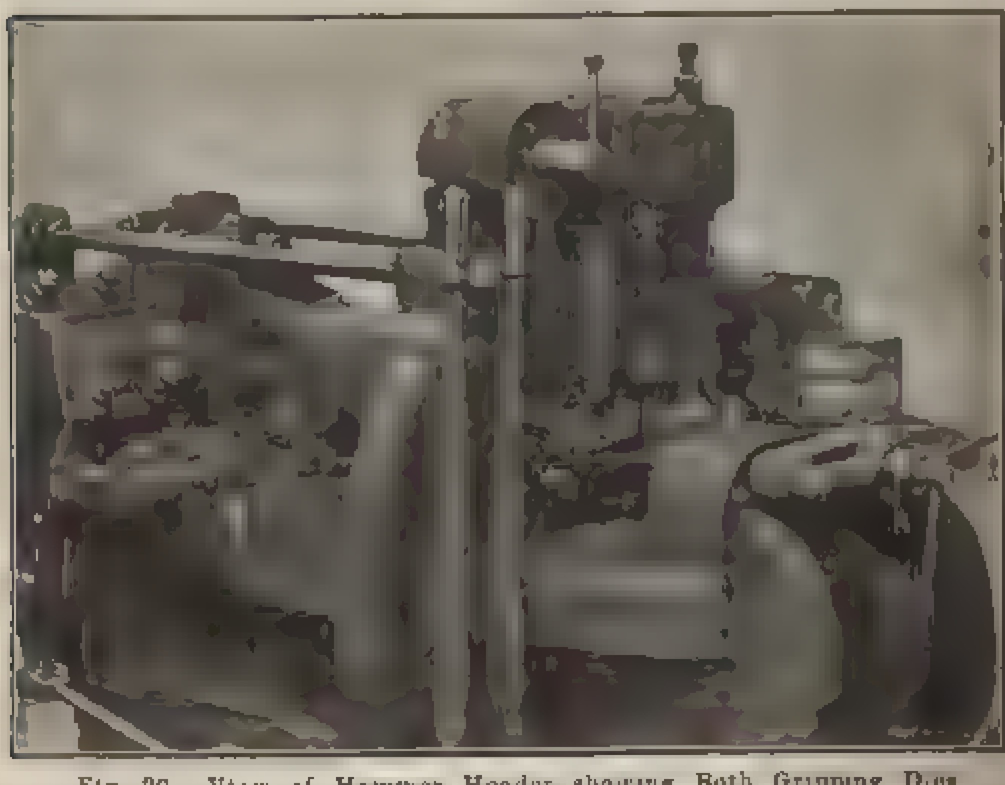


Fig. 20. View of Hammer Header showing Both Gripping Dies removed, and One Die Hanger

able stop, and the gripping dies are not opened until the head is completely formed. From three to five blows are struck, depending upon the size of the bolt and the finish desired, whereupon the machine is

stopped and the dies are opened by operating the hand-lever, allowing the finished work to drop from the machine. The side-forming hammers *D*, Fig. 20, give two blows to every blow struck by the heading tool *E* and the vertical hammers *F*.

Fig. 21. View of Hammer Header showing Left-hand Die Hanger removed, and One Gripping Die in Place

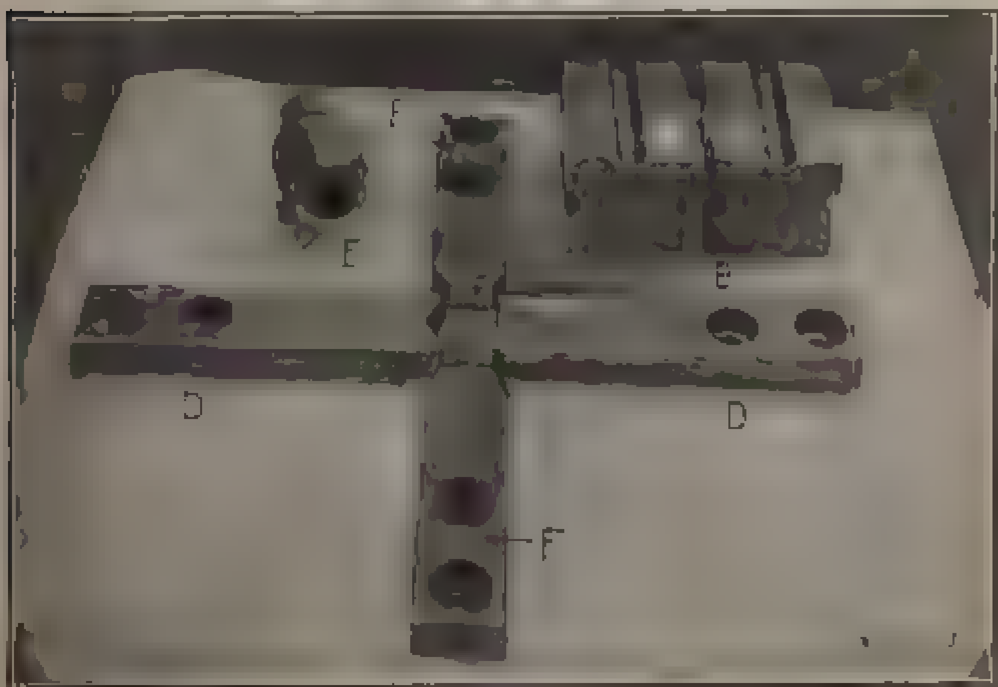
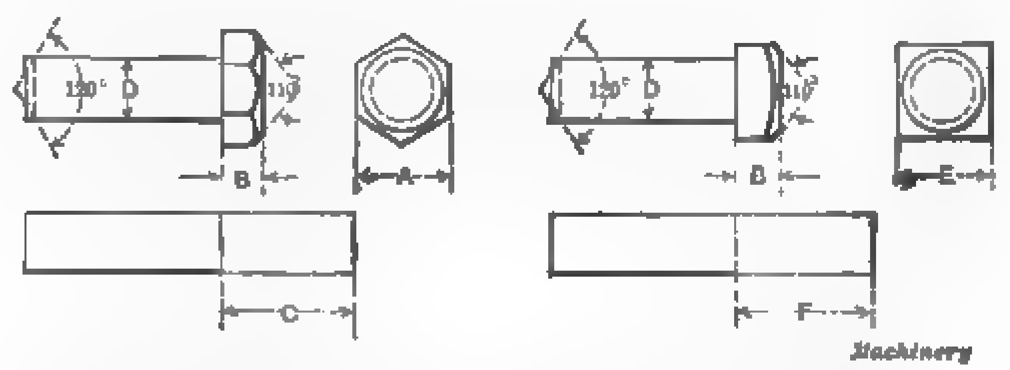


Fig. 22. Type of Dies, Hammers and Heading Tool used in the Hammer Type of Bolt Header shown in Fig. 19

The $1\frac{1}{2}$-inch size of this type of hammer header is provided with two hand controlling levers, as shown in Figs. 20 and 21. One of these levers operates the arms carrying the gripping dies, and the other operates for starting and stopping the machine. On the smaller ines, one lever controls both of these move-

ments. Fig. 20 shows one of these hammer headers with the gripping dies and the left-hand gripping die hanger removed; this view also shows clearly the upsetting punch and the four forming ham-

TABLE I. PROPORTIONS OF U. S. STANDARD AND MANUFACTURERS' STANDARD HEXAGON AND SQUARE HEAD BOLTS AND APPROXIMATE AMOUNT OF STOCK REQUIRED TO FORM HEAD



United States Standard						Manufacturers' Standard					
Dimensions in Inches						Dimensions in Inches					
D	A	B	C	E	F	D	A	B	C	E	F
1/4	1/2	1/4	1 3/32	1/2	1 5/32	1/4	7/16	7/32	21/32	3/8	11/16
5/16	19/32	19/64	1 3/16	19/32	1 3/8	5/16	17/32	1/4	3/4	15/32	13/16
3/8	11/16	11/32	1 1/4	11/16	1 1/2	3/8	5/8	9/32	27/32	9/16	15/16
7/16	25/32	25/64	1 3/8	25/32	1 5/8	7/16	23/32	11/32	1	21/32	31/32
1/2	7/8	7/16	1 1/2	7/8	1 27/32	1/2	13/16	3/8	1 1/32	3/4	1 1/16
9/16	31/32	31/64	1 5/8	31/32	1 31/32	9/16	29/32	13/32	1 1/4	27/32	1 7/32
5/8	1 1/16	17/32	1 11/16	1 1/16	2	5/8	1	15/32	1 11/32	15/16	1 11/32
3/4	1 1/4	5/8	1 15/16	1 1/4	2 7/32	3/4	1 3/16	[illegible]	1 7/16	1 1/8	1 3/8
7/8	1 7/16	23/32	2 3/32	1 7/16	2 1/2	7/8	1 3/8	11/16	1 7/8	1 5/16	1 3/4
1	1 5/8	13/16	2 3/8	1 5/8	2 3/4	1	1 9/16	3/4	2 1/32	1 1/2	2 1/32
1 1/8	1 13/16	29/32	2 21/32	1 13/16	3	1 1/8	1 3/4	27/32	2 7/32	1 11/16	2 11/32
1 1/4	2	1	2 27/32	2	3 1/4	1 1/4	1 15/16	15/16	2 7/16	1 7/8	2 21/32
1 3/8	2 3/16	1 3/32	3	2 3/16	3 9/16	1 3/8	2 1/8	1 1/16	2 23/32	2 1/16	3 1/32
1 1/2	2 3/8	1 3/16	3 5/16	2 3/8	3 13/16	1 1/2	2 5/16	1 1/8	3	2 1/4	3 7/32
1 5/8	2 9/16	1 9/32	3 1/2	2 9/16	4 1/16	1 5/8	2 1/2	1 7/32	3 1/4	2 7/16	3 15/32
1 3/4	2 3/4	1 3/8	3 3/4	2 3/4	4 3/8	1 3/4	2 11/16	1 5/16	3 17/32	2 5/8	3 3/4
1 7/8	2 15/16	1 15/32	4	2 15/16	4 5/8	1 7/8	2 7/8	1 13/32	3 25/32	2 13/16	4 5/32
2	3 1/8	1 9/16	4 1/4	3 1/8	4 7/8	2	3 1/16	1 1/2	4	3	4 5/16
2 1/4	3 1/2	1 3/4	4 21/32	3 1/2	5 7/16	2 1/4	3 7/16	1 11/16	4 7/16	3 3/8	5
2 1/2	3 7/8	1 15/16	5 3/16	3 7/8	5 15/16	2 1/2	3 13/16	1 7/8	4 25/32	3 3/4	5 5/8
2 3/4	4 1/4	2 1/8	5 1/2	4 1/4	6 7/16	2 3/4	4 3/16	2 1/16	5 3/8	4 1/8	5 31/32
3	4 5/8	2 5/16	6 1/16	4 5/8	7	3	4 9/16	2 1/4	5 11/16	4 1/2	6 7/16
3 1/4	5	2 1/2	6 1/2	5	7 9/16	..	..	..	..	..	..
3 1/2	5 3/8	2 11/16	7	5 3/8	8 1/4	..	..	..	..	..	..
3 3/4	5 3/4	2 7/8	7 1/2	5 3/4	8 13/16	..	..	..	..	..	..
4	6 1/8	3 1/16	8	6 1/8	9 9/16	..	..	..	..	..	..

mers. Fig. 21 shows the same machine with one of the gripping dies in place, but with the left-hand gripping die hanger removed. The tools used in this machine are more clearly illustrated in Fig. 22; the various members are denoted with the same reference letters as used in connection with the description of the machine. For making a

square-headed bolt, the side-working hammers, of course, are of the same shape as the vertical hammers.

The type of hammer header illustrated in Figs. 19, 20 and 21 is limited in its scope to the production of square, hexagon and tee-headed bolts as shown in Fig. 23. These, however, can be produced in large quantities at a low cost, and what is more important, the product is entirely free from fins and burrs, and is shaped as accurately as is possible by the forging method. The fact, however, that it takes longer to change the dies from one size to another in this type of machine militates against its installation in preference to the

Fig. 23. Some Examples of Work produced in National Hammer Headers

other types of bolt headers, where frequent changes in the sizes of dies are necessary.

Stock Required for Bolt Heads

In forming a head on a bolt or rivet, the heated metal on the end of the bar is upset or formed into the desired shape by a plunger held in the ram of the forging machine. To produce the head requires considerably more metal than the thickness of the head—because of the increase in diameter—and hence it is necessary to allow a certain amount of excess stock to form the head. Table I gives proportions of U. S. standard and Manufacturers' standard hexagon and square bolt heads, and also the approximate amount of stock required to form the head, this information being listed in Columns "C" and "F." The excess amount of stock given is not lose enough for starting the machine, as the stop justed to suit.

CHAPTER II

CONTINUOUS-MOTION BOLT AND RIVET HEADERS

Continuous-motion bolt and rivet headers are made in two types, one being hand-fed and the other provided with an automatic roll feed. A machine of the hand-fed type is shown in Fig. 24. In operating this type of machine, the bar, which has been heated for a length of four or five feet, is fed through a shear in the faceplate block of the machine, and as the movable gripping die closes on the bar, a blank of the required length is cut off and held rigidly in the gripping dies. The head is then formed by the forward movement of the

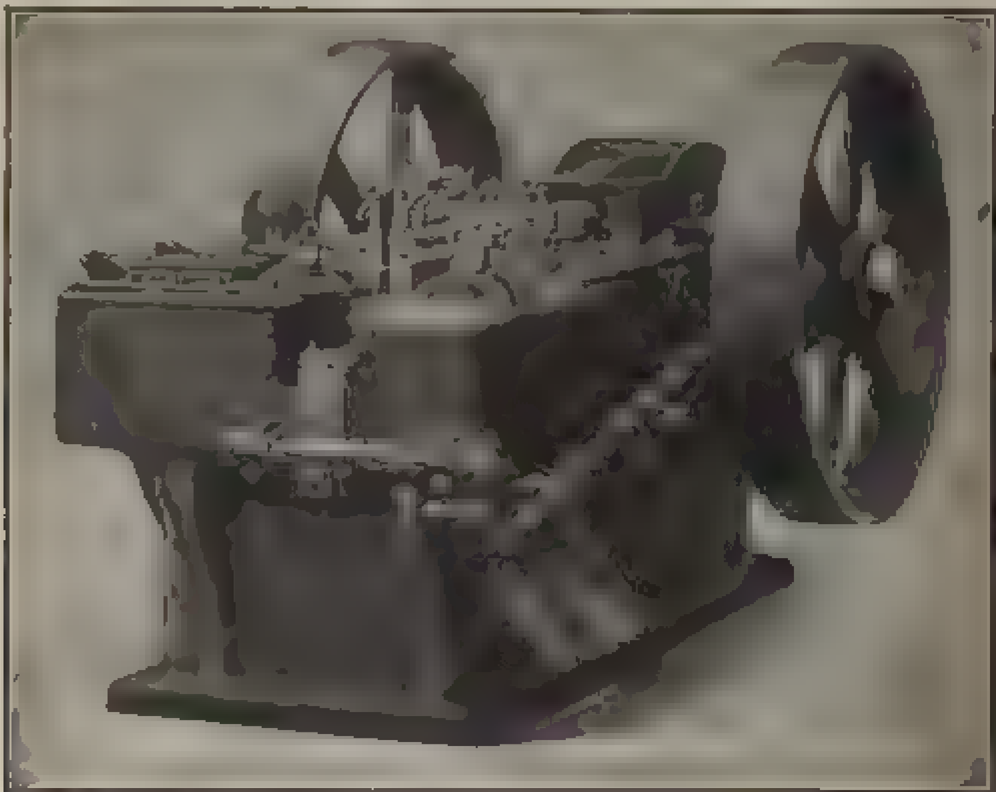


Fig. 24. Continuous-motion Wedge-grip Bolt and Rivet Header built by the National Machinery Co.

ram which carries the heading tool. After heading, the ram of the machine recedes, the gripping dies open, and a kicker, actuated by a connecting-rod c from a cam on the main shaft, ejects the finished work from the dies, depositing it, through a chute, into a box. As the dies open, the operator again pushes in the heated bar until it strikes the stop, and as the movable die advances, another blank is cut off and headed as before. The machine runs continuously until the heated portion of the bar has been exhausted, when the operator takes a newly heated bar from the furnace and proceeds as before.

A bolt or rivet made in a machine of this type receives only one blow, and, therefore, for work within the capacity of this machi the production is greatly increased over that obtained from the pl

type of forging machine. One of the chief requisites in a machine of the continuous-motion type is that of securing a rigid grip on the work while the head is being formed. If the grip is not satisfactory, that is, if the dies separate, it causes the shank of the bolt or rivet to become tapered or out of round, and also results in fins being produced on the shank and under the head. Furthermore, unless the machine is provided with suitable slides which can be kept in proper alignment, it is difficult to secure work on which the heads are centrally located with the shanks, and also to keep the shear and movable die in correct working relation.

The type of tools used in the bolt and rivet machine of the con-

Fig. 25. Type of Dies and Tools used in the Continuous-motion Bolt and Rivet Header shown in Fig. 24

tinuous-motion type is illustrated in Fig. 25. The two gripping dies *A* and *B* are held in the die space of the machine by heel clamps as shown in Fig. 24. The gripping dies are provided with four interchangeable grooves, so that when one groove wears out, it is only necessary to turn the blocks. The heading punch *C*, which is held in the holder *D* in the ram of the machine, is cupped out to suit the shape of the bolt or rivet head, and is so arranged that it will be in perfect alignment with the gripping dies. *E* is the shearing blade which is held in the faceplate block, and is used in cutting off the stock to the desired length. The length of the gripping dies is governed by the length of the bolt required; they are made shorter than

the blank from which the bolt is made, thus allowing for sufficient extra stock to form the head

Continuous-motion Bolt and Rivet Header with Automatic Feed

Fig. 26 shows a continuous-motion bolt and rivet header furnished with a roll feed attachment, which consists of four rollers provided with suitably shaped grooves in their peripheries. This view shows the roller feed attachment swung back out of the way in order to exhibit the dies and tools. This machine is similar to the one shown in Fig. 24, with the exception of the roll feed attachment for handling the bars automatically. The tools used are shown in Fig. 27, together

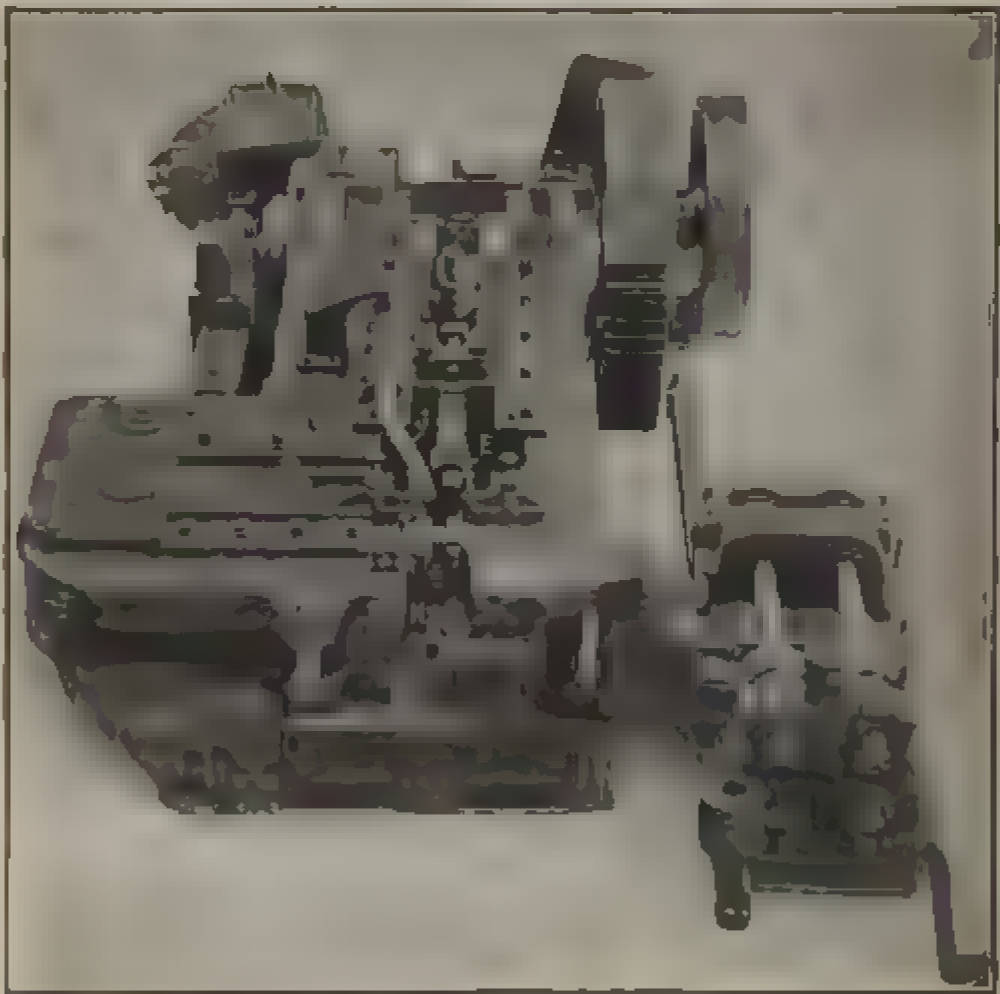


Fig. 26. Continuous-motion Bolt and Rivet Header built by the Ajax Mfg. Co., Cleveland, equipped with Roll Feed Attachment

with an example of work produced in them. The shearing die *A*, in this case, is steel bushed and is circular instead of oblong in shape. The gripping dies *B* and *C* are provided with four grooves each, as previously described, but to change the blocks for presenting a new groove, they are turned end for end, there being no grooves in the top faces. *D* is a 3/4 by 4 inch track bolt; *E* is the heading tool that is held in the ram of the machine.

A close view looking down into the die space of the machine shown in Fig. 26 is illustrated in Fig. 28. This view shows the relative positions of the feed rolls, shearing die, gripping dies, etc. The heated bar is fed by the rolls *F* through the guide pipe *G*, held by

bracket *B*, and through the shearing bushing *A*. This bushing is retained in the faceplate *I* which is held in grooves in the machine bed. The bar is fed directly through the cut-off bushing *A* and is gaged to length by the swinging stop *J* (see also Fig. 26). The movable die *C* then advances, cuts off the blank and carries it into the

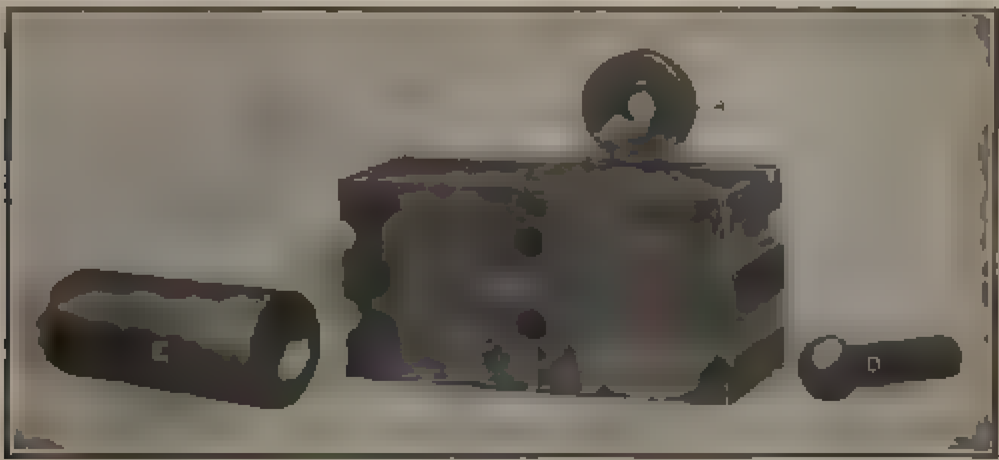


Fig. 27. Type of Dies and Tools used in Bolt and Rivet Making Machine shown in Fig. 26

groove in the stationary die *B*, gripping it while the heading tool (*E*, Fgi. 26) advances and upsets the end of the bar, forming the head.

Fig. 28. View looking down into Die Space of Ajax Continuous-motion Bolt and Rivet Header

The stationary and movable gripping dies are held in place by straps, and are located ... fitting in grooves in their lower faces. The len... ...d by the travel transmitted to the rolls through ... which receives power from the main crank ... rod, ratchet, pawl, gears, etc., and is ad... ...otor.

The various steps in the production of a round-head rivet by the continuous-motion single-blow bolt and rivet machine, are clearly illustrated in the digaram Fig. 29. At *A*, the feed rolls have operated and have fed the heated bar out against the gage stop; at *B*, the

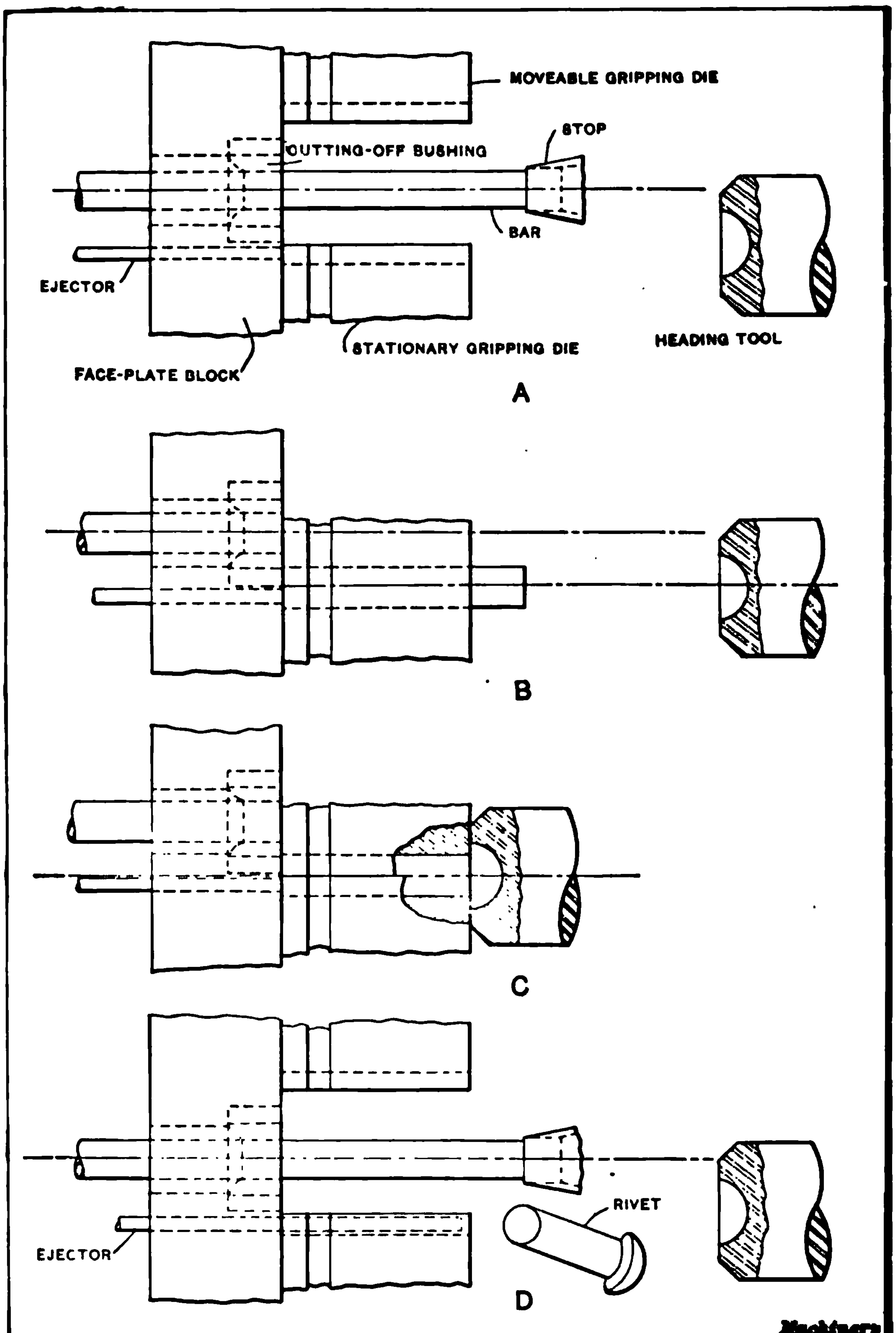


Fig. 29. Successive Steps in the Formation of a Round-head Rivet in a Single-blow Rivet Machine of the Continuous-motion Type

movable die has advanced, sheared off the end of the ba
through the shearing bushing), and carried the blank in
in the stationary die. When the blank is held rigid
words, when the movable die has reached the end

movement, the heading tool advances, as shown at *C*, and upsets the end of the bar, forming the head. At *D*, the movable die and heading tool have retreated, the ejector pin (see *K*, Fig. 26) has advanced, pushing out the completed rivet, and the bar has been fed out again ready for a repetition of the operations.

Some idea of the methods pursued in the making of bolts and rivets by the continuous-motion machine process can be obtained from Fig. 30, which shows an operator attending to one of these automatic machines. The furnace in which the bar is heated (in the condition in which it comes from the mill) is located anywhere from 3½ to 4 feet from the feed rolls of the machine, and is provided in front with a roller *A*, over which the heated bar passes. The heating furnace,

Fig. 30. Ajax Continuous-motion Bolt and Rivet Machine in Action making 1½-inch Rivets

as a rule, is 30 feet long, so that the entire length of a bar can be accommodated.

As soon as the bar in the furnace has reached the proper temperature, the operator grips it with a pair of tongs, as indicated in Fig. 30, draws it out, and places it between the feed rolls. Then he presses down the foot-lever *B*, thus starting the machine. The heated bar is then drawn in by the rolls, fed through the cutting-off die, gripped in the gripping dies, headed and ejected at the rapid rate of forty to [illegible] pieces per minute.

[illegible] 'acture of rivets, as a rule, steel containing from 0.10 [illegible] 'arbon is more frequently used than wrought iron, [illegible] material is used in considerable quantities in [illegible] ablishments. Wrought iron for making rivets

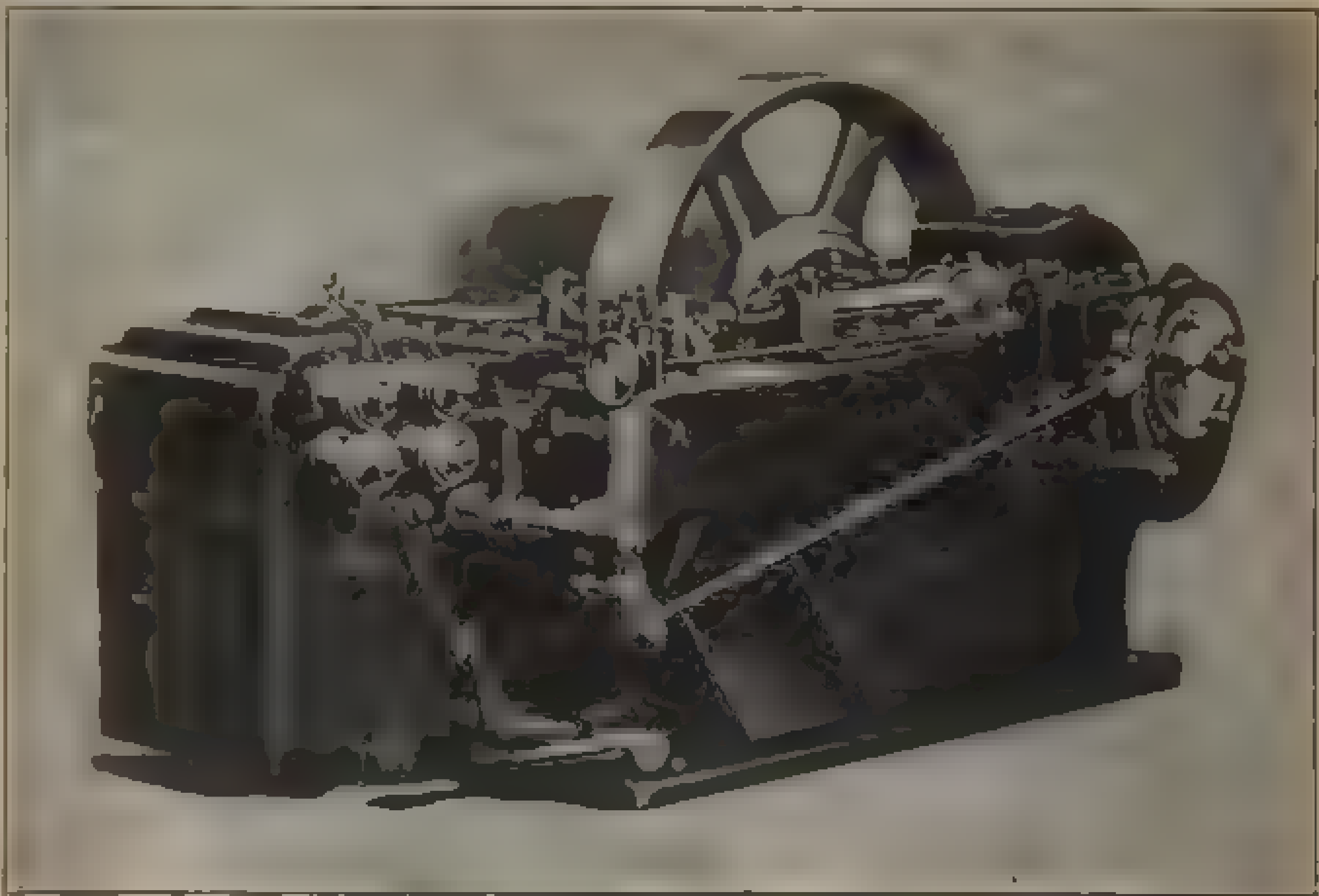


Fig. 31. National Continuous-motion Bolt and Rivet Making Machine equipped with Roll Feed and Adjustable Stop Gage

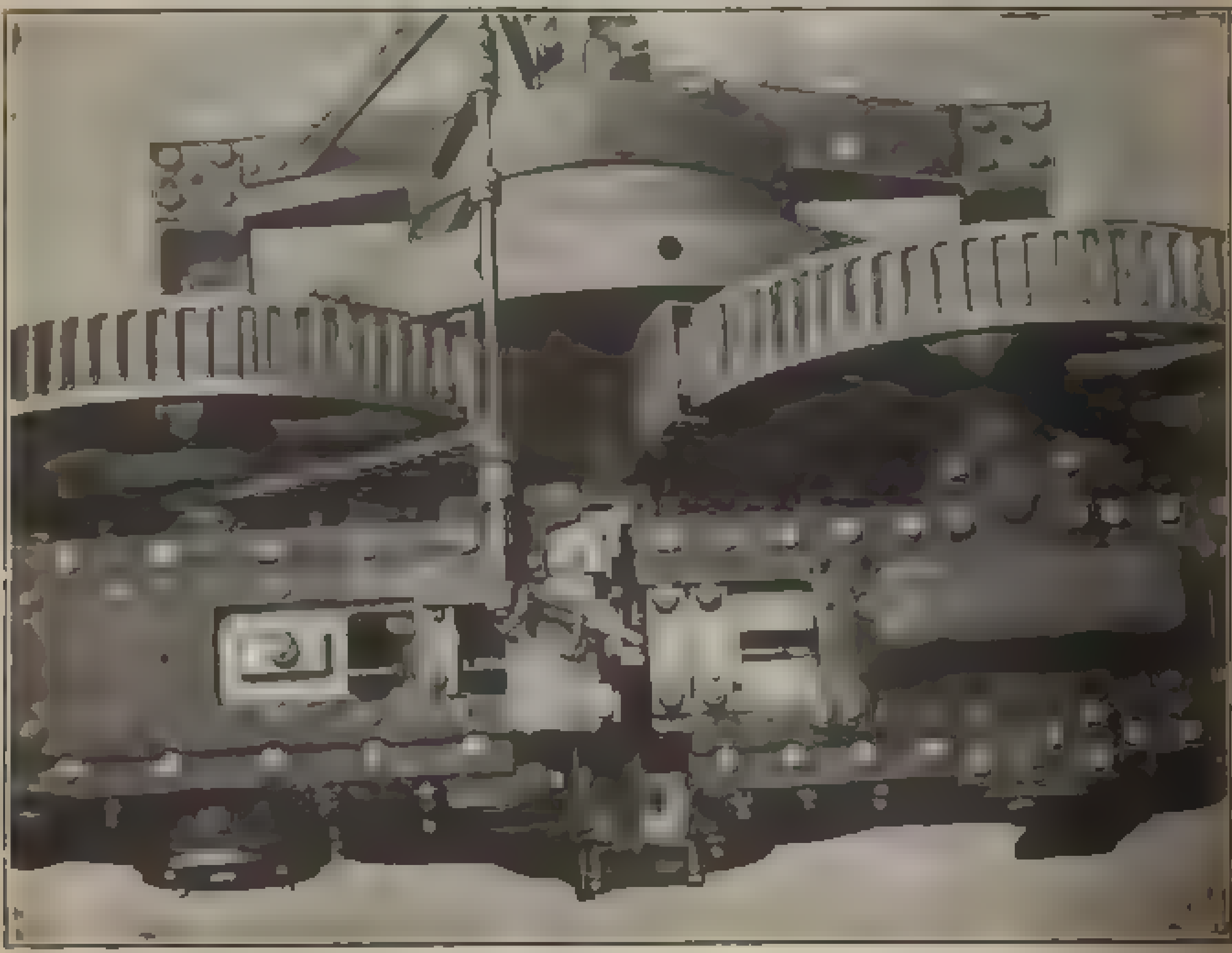


Fig 32 Top View of National Hot-pressed Center feed Nut Making Machine

is heated to almost a white heat, but steel which contains from 0.10 to 0.12 per cent carbon is heated to only about 1400 degrees F.—a bright red color. When the head of a rivet is so shaped that it is necessary to carry the stock down far into the heading tool, the temperature to which the bar is heated must be increased, in order to make the metal flow more readily and prevent buckling.

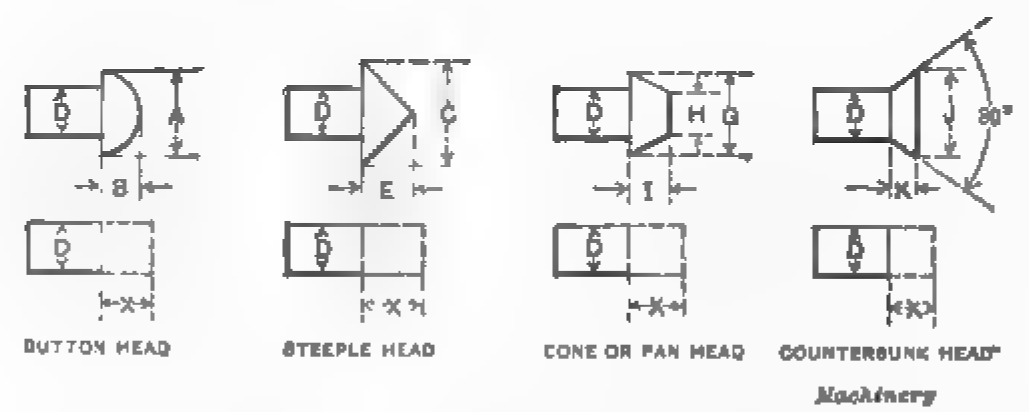
In making rivets with long tapered heads, the operator generally finds it necessary to change the length of feed, so that a rivet having a full head without flash is formed. The reason for this is that the bars sometimes vary in size and temperature, which makes this adjustment necessary. A continuous-motion bolt and rivet making machine, which is provided with means for taking care of the fluctua-

Fig. 33. Some Examples of Work which come within the Range of the Continuous-motion Type of Bolt and Rivet Headers

tions in size and temperature of stock, is shown in Fig. 31. In this machine the position of the stop is controlled by a handwheel A, within convenient reach of the operator, which he adjusts either way, depending upon the size of the bar, temperature of the metal, the shape of the part to be produced and the material from which it is made. When an over-size bar is encountered, the operator shortens the length of feed, as it is evident that too much stock would otherwise be supplied. When the bar is under-size, the reverse is the case. Again, when the bar is too hot, it is upset more on the end by the rolls forcing it against the stop, e[illegible] more metal is provided than when the bar is not [illegible] [illegible]ently harder. The operator watches the pieces [illegible] machine, and then adjusts the stop to kee[illegible] possible—having a full head and with[illegible]

The feed rolls in the machine shown in Fig. 31 are made of chilled iron castings, and are kept cool by water jackets, insuring even temperature and minimum wear. They are operated from the main-shaft of the rolls. The movements of the machine are timed so as to allow ment as shown, adjustable for securing variations in the feeding time of the rolls. The movements of the machine are timed so as to allow the gripping dies to remain open a comparatively large part of the

TABLE II. DIMENSIONS OF RIVET HEADS OF VARIOUS SHAPES



Dimensions in Inches									
D	A	B	C	E	G	H	I	J	K
1/4	7/16	3/16	1/2	1/4	7/16	1/4	7/32	[illegible]	1/8
5/16	35/64	15/64	5/8	5/16	35/64	5/16	17/64	[illegible]	5/32
3/8	21/32	[illegible]	3/4	3/8	21/32	3/8	21/64	[illegible]	3/16
7/16	49/64	21/64	7/8	7/16	49/64	7/16	3/8	[illegible]	7/32
1/2	7/8	3/8	1	1/2	7/8	1/2	7/16	[illegible]	1/4
9/16	1	27/64	1 1/8	9/16	1	9/16	1/2	1 1/32	9/32
5/8	1 3/32	15/32	1 1/4	5/8	1 3/32	5/8	35/64	1 3/32	5/16
11/16	1 3/16	33/64	1 3/8	11/16	1 3/16	11/16	19/32	1 1/4	11/32
3/4	1 5/16	9/16	1 1/2	3/4	1 5/16	3/4	21/32	1 3/8	3/8
13/16	1 7/16	39/64	1 5/8	13/16	1 7/16	13/16	45/64	1 1/2	13/32
7/8	1 17/32	21/32	1 3/4	7/8	1 17/32	7/8	3/4	1 19/32	7/16
15/16	1 5/8	45/64	1 7/8	15/16	1 5/8	15/16	13/16	1 11/16	15/32
1	1 3/4	3/4	2	1	1 3/4	1	7/8	1 25/32	1/2
1 1/16	1 27/32	51/64	2 1/8	1 1/16	1 27/32	1 1/16	15/16	1 29/32	17/32
1 1/8	1 31/32	27/32	2 1/4	1 1/8	1 31/32	1 1/8	1	2 1/16	9/16
1 1/4	2 3/16	15/16	2 1/2	1 1/4	2 3/16	1 1/4	1 3/32	2 3/16	5/8
1 3/8	2 13/32	1 1/32	2 3/4	1 3/8	2 13/32	1 3/8	1 3/16	2 13/32	11/16
1 1/2	2 5/8	1 1/8	3	1 1/2	2 5/8	1 1/2	1 5/16	2 5/8	3/4

revolution, thereby allowing more time for the stock to be fed in and gaged, and the dies to be well flooded and cooled at the completion of each stroke.

Examples of Continuous-motion Bolt and Rivet Work

Inasmuch as only one blow can be struck in a continuous-motion bolt and rivet making machine, it is impossible to produce parts which cannot be completed in one blow. Fig. 33 shows a representative group of bolts and rivets for which the continuous-motion machines are especially adapted. These machines will also handle a

great variety of special work, such as square and hexagon head single-blow bolts, track bolts, etc. The cone-shaped rivets *A* and *B* illustrate the point mentioned in a previous paragraph regarding the difficulty encountered in producing work which is carried down far into the heading tool. Of course, these are not by any means extreme examples, but they serve to illustrate the point.

Making Bolt and Rivet Dies

Bolt dies which are used in a forging machine are as a rule made from steel containing from 0.60 to 0.80 per cent carbon, and are hardened and drawn. The gripping dies are tempered hard, so that the sharp corners on the edges of the dies will not wear away rapidly. It is customary to harden these dies in either oil or water, and then draw the temper so that a file will just take hold. The heading tool, which is comparatively small in diameter, and is called upon to perform heavy duty, must be much tougher than the gripping dies. Ordinarily the heading tool is made from a tough steel containing from 0.40 to 0.50 per cent carbon, and is drawn considerably more than the gripping dies.

In making the impressions in the gripping dies for heading ordinary sizes of bolts, no allowance is made for the shrinkage of the metal. However, in drilling the hole in the dies which grip the stock when it is being headed, a liner is placed between the two halves of the die, so that when they come together on the stock, the latter will be securely held. For dies with a 1/4- to 5/8-inch hole, a liner 1/64 inch thick is placed between the opposing faces, when drilling the hole. For holes larger than 5/8 inch and up to 1 inch, a liner 1/32 inch thick is used; for holes from 1 inch up to 1 1/2 inch in diameter, a liner 3/64 inch thick is used; and from 1 1/2 inch up to and including 2 inches in diameter, a liner 1/16 inch is employed. The double-deck type of dies are made from six blocks of steel bolted and keyed together to facilitate machining.

In making bolt and rivet dies which are used in continuous-motion machines, it is customary when making rivets from 1/2 to 1 inch in diameter, to use bar stock which is rolled 1/64 inch under-size. The dies referred to are shown in Figs. 25 and 27. The holes in the gripping dies are drilled to exact size (not 1/64 inch under-size, which is the diameter of stock used), and the expansion of the iron in heating gives sufficient grip, as it is only necessary to prevent the rivets from being pulled out of the dies by the return stroke of the heading tool. The reason for this is that in the continuous-motion type of bolt and rivet machine, the work is supported on the sides by the gripping dies, and is backed up by the shear, so that it is practically held in a box while the head is being formed. The same grade of steel is used for making rivet tools as for [illegible] tools for producing bolts, and the heat treatment is al[illegible] in a similar manner.

Stock Required for Rivet Heads

In making rivets in a continuous-motion rivet machine, the amount of excess stock (X, Table II) required is generally obtained by trial, but when definite shapes and proportions of rivet heads have been decided upon, the amount of excess stock required can be calculated approximately. The great difficulty in giving tables covering the amount of excess stock required is that no standard for rivet heads is universally followed, with the result that a slight difference in the curve or height of the head changes the amount of stock necessary. In addition to this, the scale of the furnace, depending upon whether gas, oil or coal is used for heating, so changes the amount of stock required that a special setting of the stop in different cases is required. This is one of the reasons why up-to-date continuous-motion rivet making machines are provided with stops which can be adjusted while the machine is in motion. It is evident, therefore, that the exact amount of stock required is a question of some nicety, and it is surprising to what extent even the scaling off in the furnace will affect the stock required for the rivet head. What are considered in some shops standard shapes and sizes for rivet heads are given in Table II.

CHAPTER III

NUT FORGING MACHINES

The plain type of upsetting and forging machine which is used to a certain extent in the manufacture of bolts and rivets, especially the larger sizes, is also used for producing the ordinary square and hexagon nuts in sizes from 2 inches up. In making nuts by this process, the diameter of the round bar from which the nut is made should not exceed the root diameter of the thread in the finished nut, so it is evident that an extremely large upset is required to produce a full nut. When large nuts are produced in a plain forging machine, the usual method is first to form an upset on the end of the bar and then pierce the hole in the nut by punching the bar back, the metal removed to form the hole in the nut being attached to the bar. This operation requires considerable pressure, and as little, if any, material is wasted, it is a very successful method of producing nuts 2 inches and larger on a commercial basis. In the following, two types of machines, especially built to produce square and hexagon nuts, will be described. One of these machines is known as the hot-pressed center-feed nut machine, and the other as the hot-forged type; the latter is applicable only to the production of square nuts.

Hot-pressed Center-feed Nut Machine

The hot-pressed center-feed nut machine, as its name implies, produces nuts by pressing a heated blank of iron or steel into the required shape, the latter first being cut off as the bar is fed into the machine. The bar stock, which is rectangular in shape, is fed in from the side through a recess in the center of the machine and placed in front of the face of the dies. Fig. 34 shows one type of center-feed hot-pressed nut machine that works on the principle just stated. This machine consists essentially of two movable rams or slides which carry the cutting-off, crowning, piercing and wad-extracting punches, respectively. One ram is operated directly from the main crankshaft, while the other is operated by eccentrics and a connecting-rod.

Fig. 35 shows a detail view of this machine, and gives some idea of the construction of the dies, tools, etc. Here A is the cutting-off punch, B the crowning punch, C the piercing punch, D the wad extractor, E the nut dies, and F the ejector. The pipes G furnish a copious supply of water to keep the dies and [illegible] in operation. A device for centering the bar in rel[illegible] and tools is shown at H.

Another center-feed hot-pressed nut mac[illegible] hexagon and square nuts in the same manne[illegible]

Fig. 34. Side View of "Ajax" Hot-pressed Center feed Nut Machine showing Operating Side and Water Pipes for cooling Dies and Tools

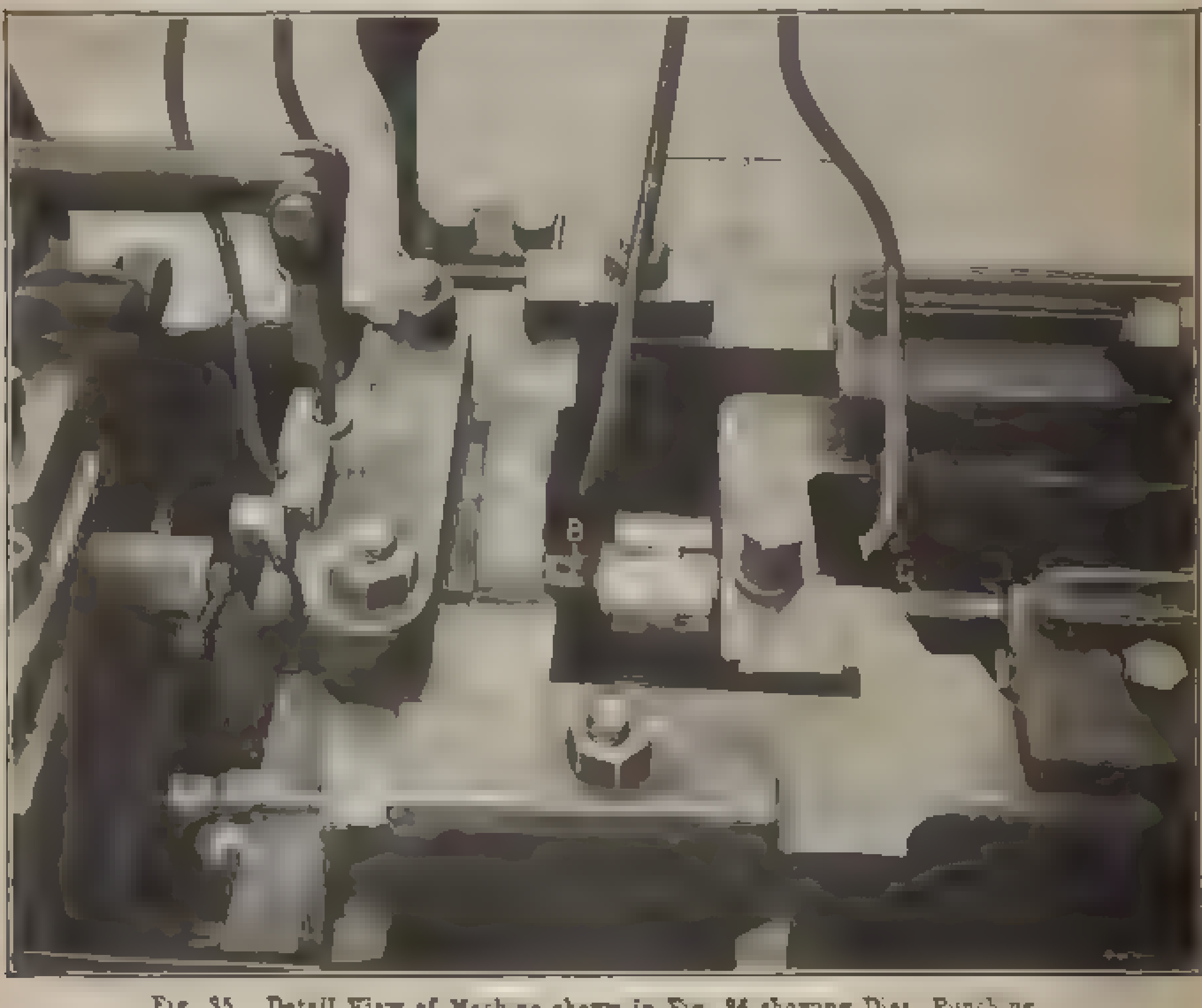


Fig. 35. Detail View of Machine shown in Fig. 34 showing Dies, Punching Piercing, Crowning Tools, etc.

34 is shown in Fig. 32. In this machine, however, both rams or slides are operated directly from the source of power by a pinion and two large gears, one gear driving each slide. The majority of manufacturers produce nuts from a material known as soft, mild, open-hearth steel, which has a comparatively fine grain, and consequently, when forged, has less tendency to crack than does wrought iron. It can also be threaded much easier and with a smoother finish than wrought iron, owing to the fact that great difficulty is met with in

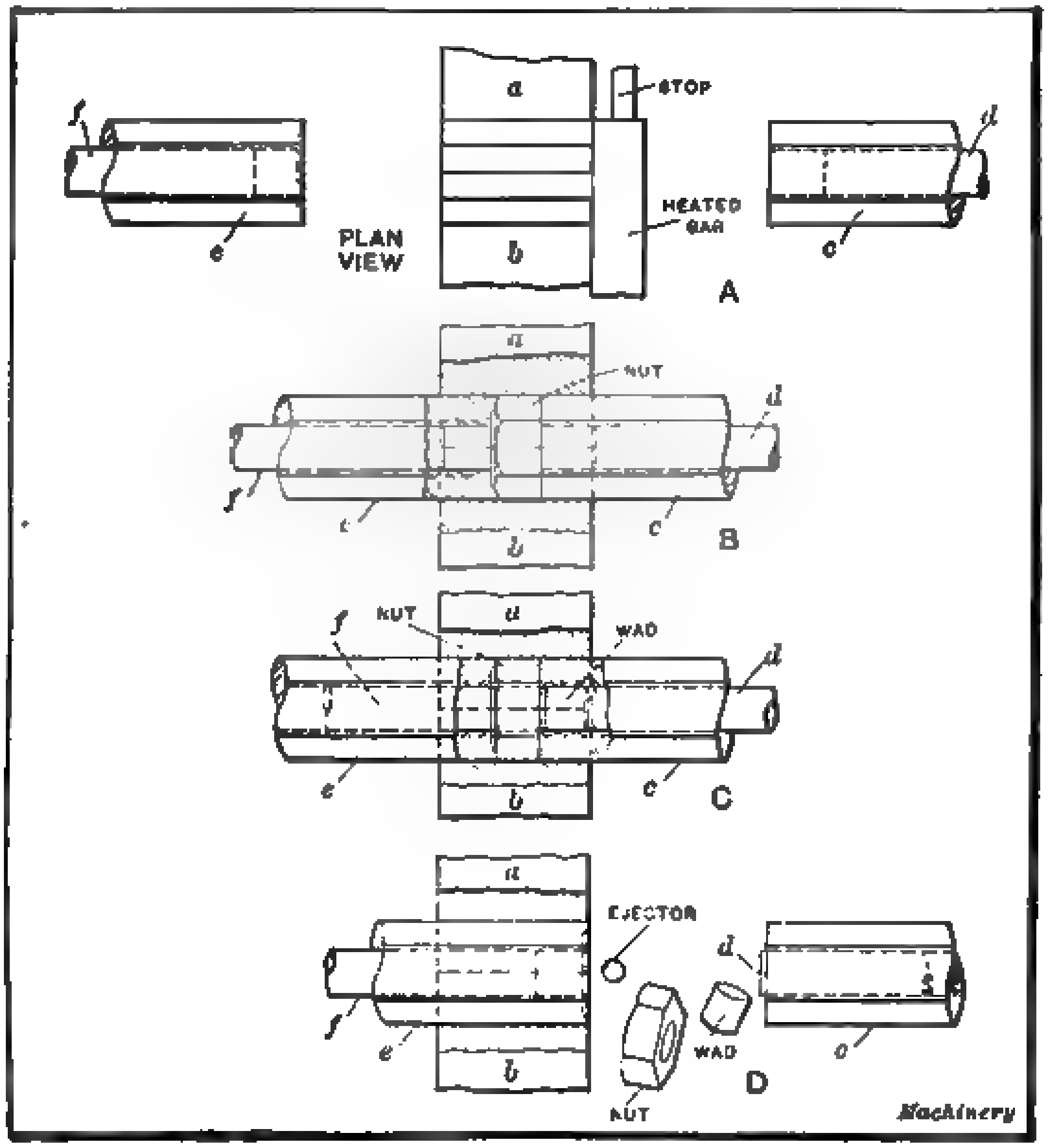


Fig. 36. Diagram illustrating Sequence of Operations in making Nuts in a Hot-pressed Center-feed Nut Machine

working the latter material, because the grain opens up, thus making it difficult to thread. Wrought iron, however, has one point in its favor—it can be worked at a much higher temperature than steel without affecting its structure, and hence does not need to be handled quite so carefully.

Operation of a Center-feed Hot-pressed Nut Machine

In operating a center-feed hot-pressed nut machine, the rectangular bar is heated to the correct temperature for a length of four or five feet. It is then brought to the machine and fed in from the side in

front of the face of the main dies, as indicated at *A* in Fig. 36. The cut-off tool *c* then moves up and shears the blank from the end of the bar, carries it into the main dies *a* and *b*, and presses it against the crowning tool *e*, which has also advanced, as indicated at *B*. The piercing tool *f* now advances, punches the hole in the nut, and carries the wad into the cutting-off tool, as shown at *C*; then the cutting-off and piercing tools *c* and *f* recede, and the crowning tool *e* advances, forcing the nut out of the dies. As the cut-off tool *c* recedes, the extractor *d* forces the wad out of the punch at the same time as the nut is ejected from the dies. The ejector, which is operated by a lever and cam, as shown in Fig. 32, is provided to prevent the nut from adhering to the crowning tool; this very seldom happens, however. A completed nut is produced at each revolution of the large gears.

The operations just described are repeated until the heated portion of the bar has been used up, after which the operator places the bar in the furnace to be re-heated, takes a freshly heated bar from the furnace, and proceeds as before. The machine is run continuously,

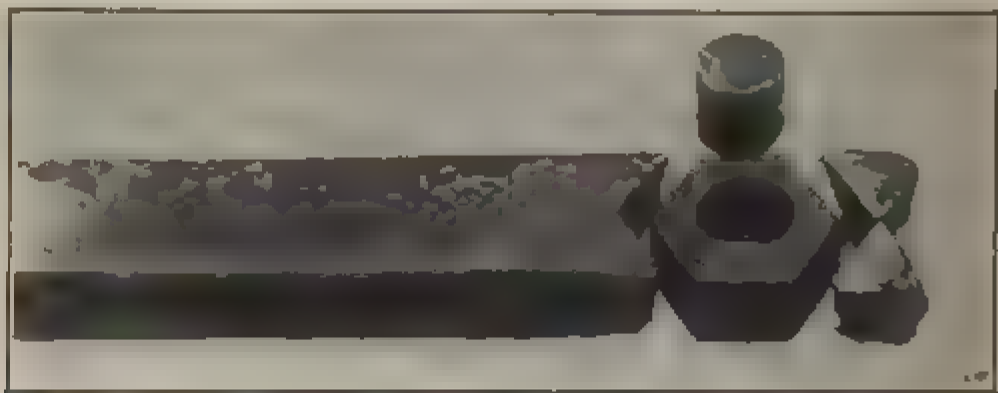


Fig. 37. Showing how a Hexagon Nut is produced from Rectangular Bar in a Hot-pressed Nut Machine

and is not stopped for the insertion of a newly heated bar. Finished nuts are turned out at the rate of from 40 to 70 per minute, depending upon the size of the machine and the skill of the operator. Fig. 37 shows how a hexagon nut is produced from a rectangular bar of stock in a center-feed hot-pressed nut machine. It will be seen that considerable scrap is lost in the production of a nut of hexagon shape, *viz.*, the wad removed to form the hole, and the triangular pieces which are removed to form the corners. On a square nut the material wasted is not quite so great, as in this case only the wad and a slight amount of stock, sheared off the end of the bar to form a square corner, are removed.

There are two common methods in use in nut forging. One is to set the stop so that the rounded corner of the bar is sheared off, leaving a square corner. This, of course, wastes somewhat more stock than the other method, yet to be described, but has the advantage of producing a perfect nut. The rounded corner is caused by the cut-off tool which, in removing the block of metal from the end of the bar to form the nut, rounds over the end of the bar, due to the hot metal

drawing over, and thus makes this waste of stock necessary if a full shaped nut is to be secured

Another method in common use to save stock and at the same time produce a practically full nut, is to invert the bar after each stroke of the machine. By this method opposite sides of the bar are alternately presented to the dies, which overcomes, to a large extent, the effect of the fin on one side and the rounded corner on the other, and produces a full nut without shearing any material from the end of the bar. The only objection to this method is the necessity of turning the bar, which, if heavy, soon tires the operator. On the larger sizes of nuts, the first method is used, as the bars are quite heavy

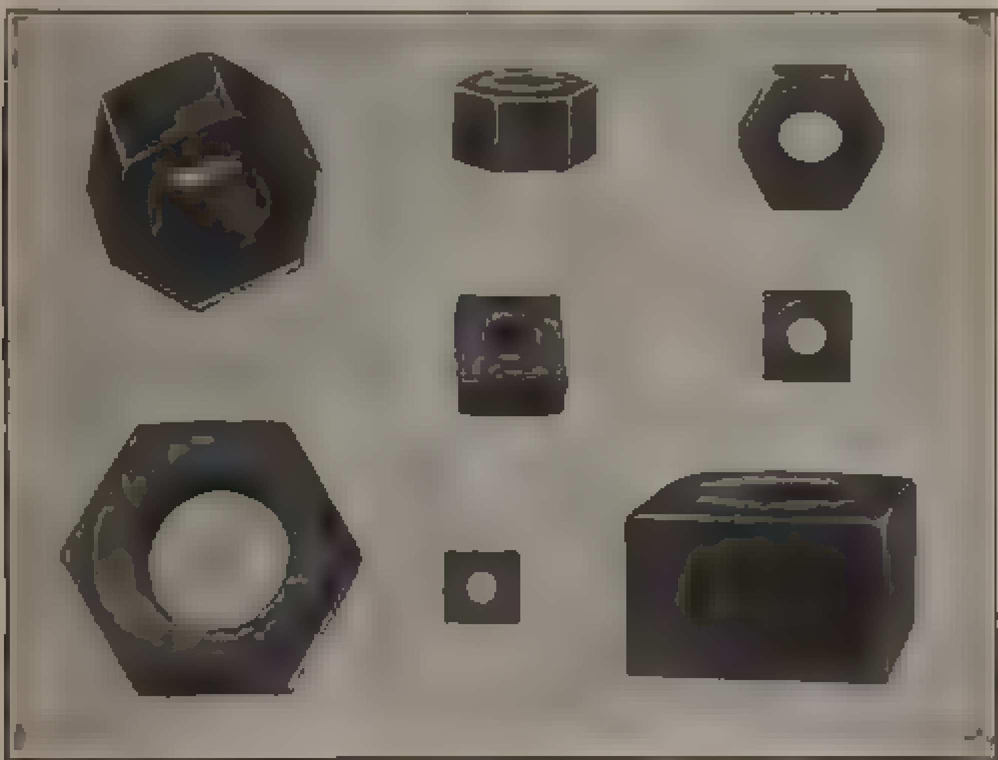


Fig. 38. Group of Square and Hexagon Nuts showing Character of Work turned out in Hot pressed Nut Machines

and the operator would find it difficult to turn them and keep up with the operation of the machine.

Fig 38 shows a typical group of nuts which can be produced economically and on a commercial basis in the center-feed hot pressed nut machine. In this illustration two of the nuts show fins on the under side, both around the outer edges and the hole. This is caused by the sharp edges of the cut off tool becoming rounded and allowing the hot metal to "leak" past the edges The clearance allowed between the cut-off punch and dies also tends to produce a slight fin. When the tools are new the burr or fin produced is very slight, but it increases as the tools wear These fins are removed in a succeeding operation in a burring machine.

Hot-forged Nut Machine

Fig. 39 shows a type of nut making machine which is only applicable to the manufacture of square nuts, but produces this class of nuts free from fins and burrs at a rapid rate Nut manufacturers who

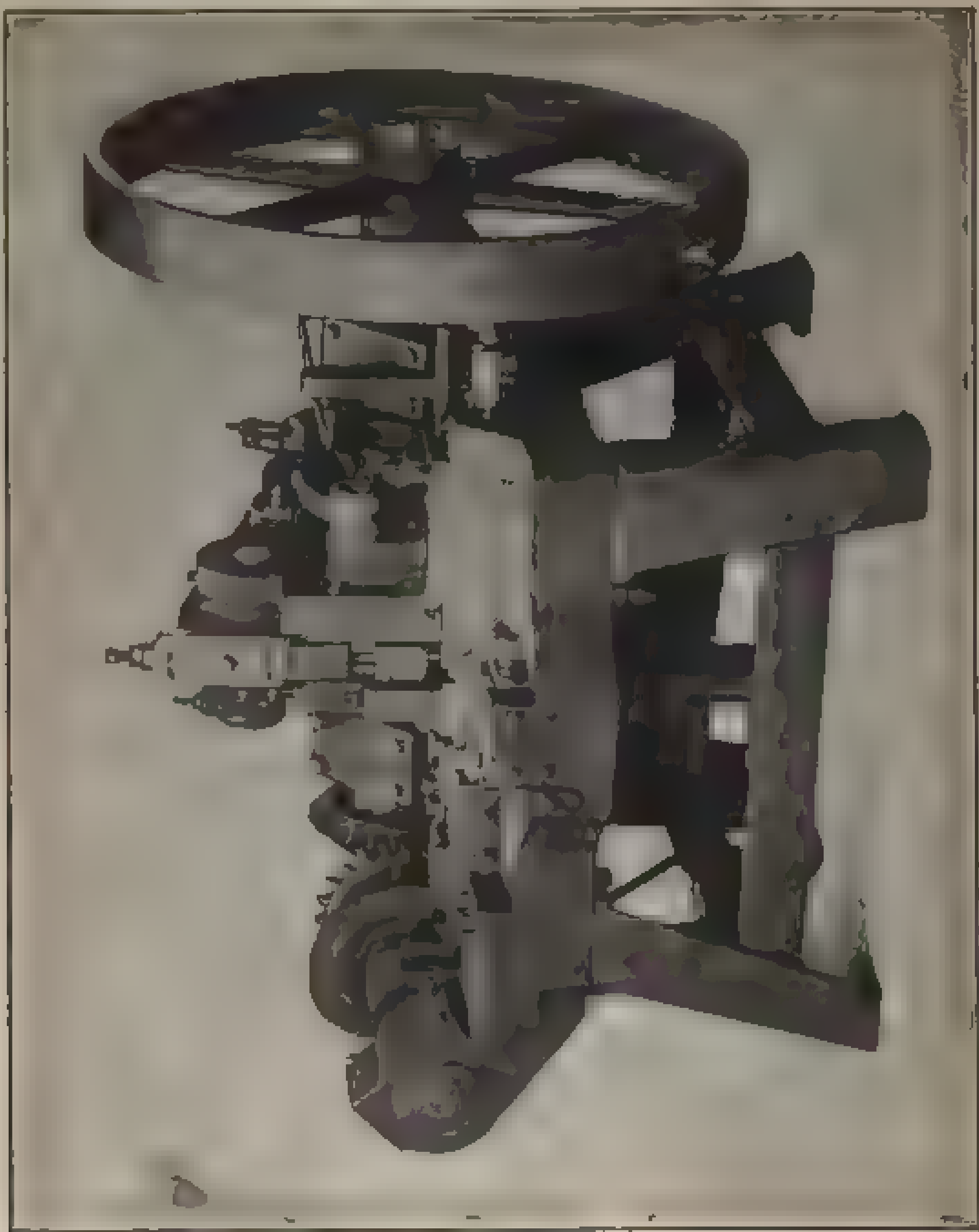


Fig. 39. "National" Hot-forged Nut Machine used exclusively for the Manufacture of Square Nuts from Rectangular Bar Stock

produce in great quantities are extensive users of this type of machine, but a concern making a variety of nuts in small quantities should not attempt to use it, owing to the delay incident to changing the dies and tools from one size to another. Briefly stated, the machine consists principally of a suitable mechanism for operating a shearing and crowning tool, four horizontal hammers which form the four sides of a square nut, and piercing and flattening punches. Power is transmitted from pulley *A* to the two shafts *B* and *C* located at right angles to each other and connected by miter gears. Shaft *C* carries eccentrics and cams which operate the left side hammer and sizing tool for gripping the bar while it is being sheared; and shaft *B*, through cams, levers and eccentrics, operates the blank shearing tool, nut ejector, front and rear hammers, piercing punch and flattening tools.

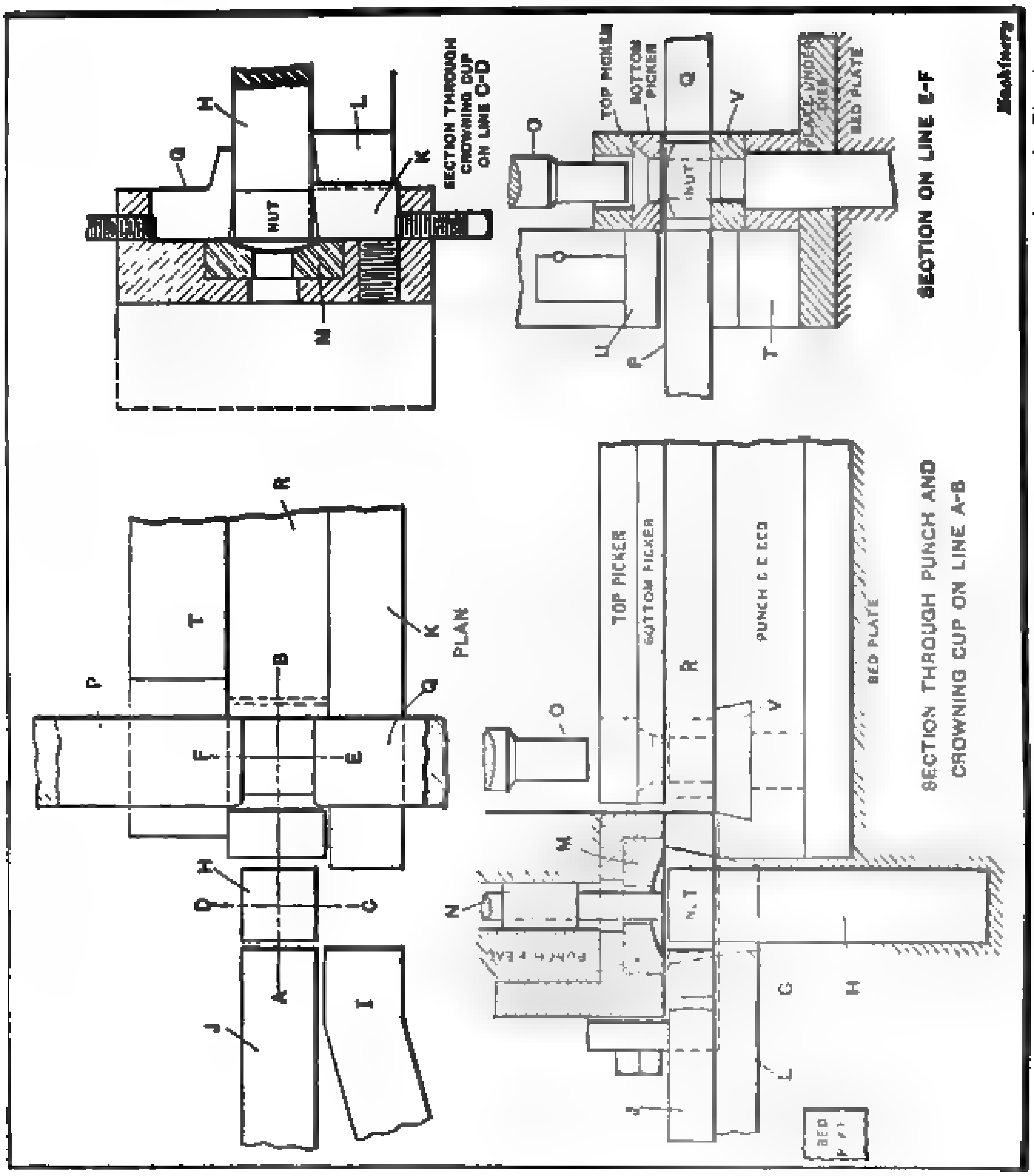


Fig. 40. Construction of Tools and Operation of the Hot-forged Type of Nut Machine shown in Fig. 39

Operation of Hot-forged Nut Machine

In order to illustrate how this hot-forged nut machine produces square nuts, the diagrams shown in Fig. 40 are included. These views show plan and sectional elevations which illustrate the relative positions of the various dies and tools, and the stages through which the nut passes before being ejected. In operating this machine, rectangular bar stock heated to a length of four or five feet is fed into the machine (see *D*, Fig. 39) along the line *CD*. The stock is equal in width to the diameter of the nut across the flats, and of the same thickness as the nut. It is fed into the machine with the greatest width horizontal and is located by the gage *G*.

As the heated bar is fed in, a shearing tool *H*, operated from the bottom of the machine, forces the heated end of the bar against the knife *K* and cuts off

a suitable blank; as this tool continues to rise, it presses the nut blank into the crowner cup *M*, which is located directly above the shearing tool. While the shearing operation is taking place, the sizing tool *I*, which moves in a line parallel with the side hammer *J*, holds the bar tightly against the stationary sizer *K*.

Gripping the bar in this manner tends to give a better shearing cut. The shearing tool *H* is now lowered until its top face is in line with the bottom of the side hammer *J*, and at the same time the kickout *N*, operated through a hole in the crowner *M*, ejects the nut, preventing it from sticking in the cup. The shearing tool now remains in its "down" position while the side hammer *J* carries the nut along line

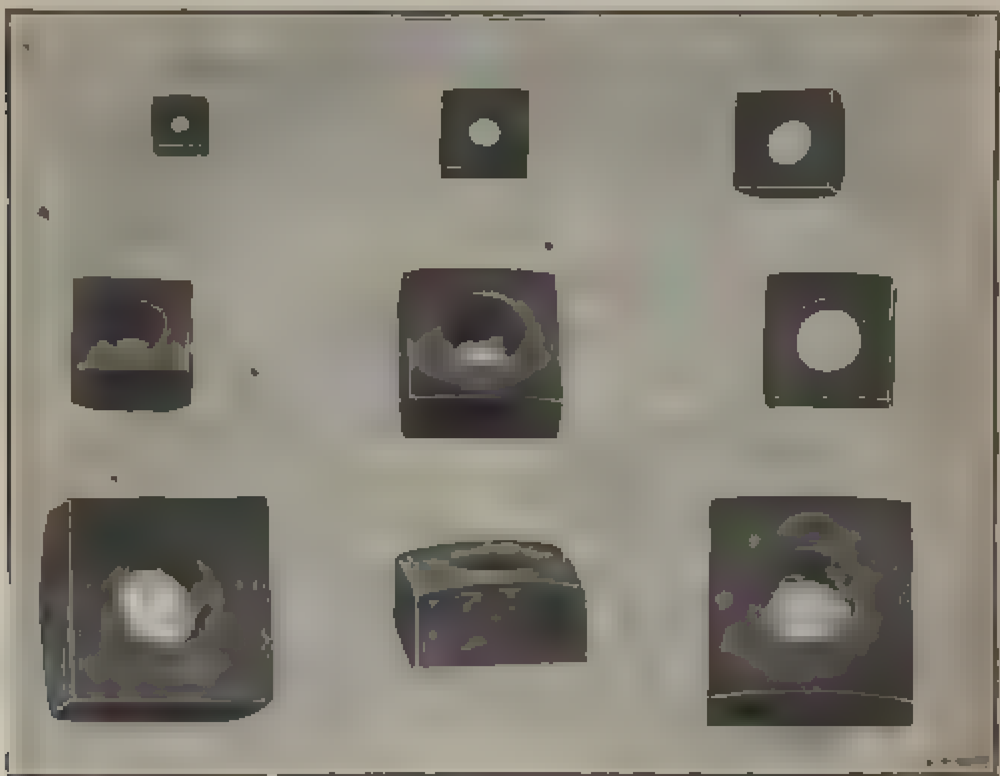


Fig. 41. Samples of Square Nuts produced on Hot-forged Type of Nut Machine—Note Absence of Burrs or Fins

AB until the center of the nut is in line with *EF* and directly under the piercing punch *O*.

As the side hammer *J* moves the nut blank under the piercing punch, the rear hammer *P* advances and presses the nut into the square box formed by the side hammer *J*, rear hammer *P*, stationary hammer *R* and front hammer *Q*. This tends to square up the sides of the nut and form it to the proper shape. While in this position, the punch *O* pierces the hole in the nut, forcing the wad through the die *V*, and immediately withdraws. The rear hammer *P* and side hammer *J* then return to their original positions, and the front hammer *Q* moves the nut back to the flatter bed *T*, which is located directly under the rear hammer *P*. While the nut is located on the flatter bed, the flattening tool *U*, which is over the rear hammer, comes down onto the nut, gives it a slight squeeze, which corrects any distortion of the top and bottom faces caused by the squeezes between the four hammers previously described, and also serves to flatten any

fins resulting from the piercing operation. The flattening tool U then rises, and the flatter bed T withdraws, allowing the finished nut to drop out of the machine. A completed nut is made at each revolution of the flywheel, and the machine is operated at from 60 to 90 revolutions per minute, depending upon its size.

Some idea of the character of the work turned out by the hot-forged nut machine can be obtained from Fig. 41, which shows a representative group of square nuts just as they come from the machine. The nuts produced by these machines are entirely free from fins or burrs, are of excellent finish, and are ready for tapping directly after being forged.

Dies and Tools Used in Hot-pressed Center-feed Nut Machines

The type of dies and tools used in the hot-pressed center-feed nut machine shown in Fig. 32 is shown in Fig. 42. The reference letters

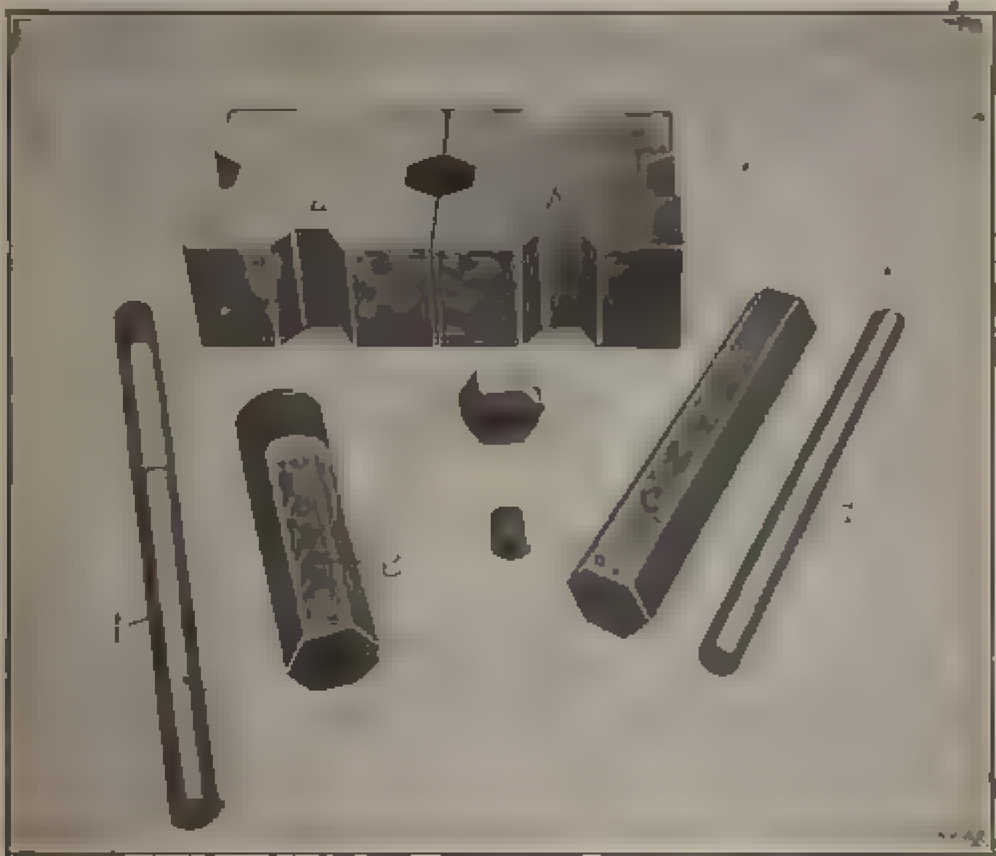


Fig. 42. Type of Dies and Tools used in making Hexagon Nuts in Center-feed Hot-pressed Nut Machine shown in Fig. 32

used here are the same as those in Fig. 36. The dies a and b, which are reversible, are usually made from chilled iron castings, and are ground to size. Dies made from this material, it is claimed, will last fully eight times as long as those made from ordinary carbon steel, but as it is somewhat of a problem to get the proper amount of "chill," many manufacturers are using a good grade of open-hearth steel instead. A crucible steel which has been found to give good results for this class of work contains from 0.90 to 1.10 per cent carbon. Some nut manufacturers have found that a certain grade of vanadium alloy steel having a carbon content of from 0.15 to 0.30 per cent

gives excellent results when used for nut dies. In all cases, of course, it is necessary to harden the dies, and those made from crucible tool steel are hardened and drawn so that they can just be touched with the file, or in other words, the temper is drawn to a light straw color.

The composition of vanadium steel used for dies varies. Two grades of vanadium tool steel are recommended for forging machine dies by the American Vanadium Co., of Pittsburg, Pa. One is composed of carbon, 0.50 per cent; chromium, 0.80 to 1.10 per cent; manganese, 0.40 to 0.60 per cent; vanadium, not less than 0.16 per cent; silicon, not more than 0.20 per cent.

The heat-treatment recommended for this steel is as follows: Heat to 1550 degrees F. and quench in oil; then reheat to from 1425 to 1450 degrees F., and quench in water, submerging the face of the die only.

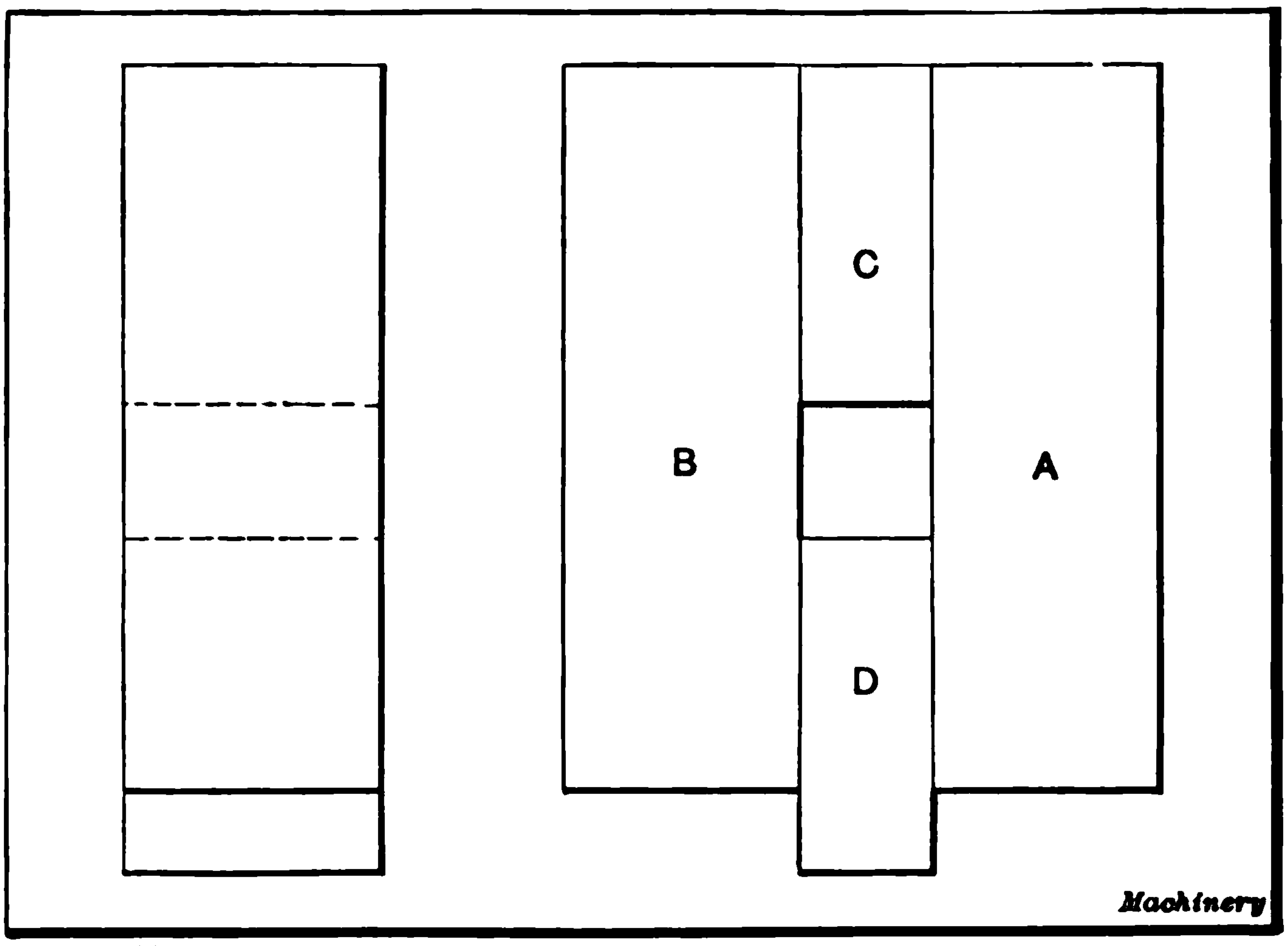


Fig. 43. Type of Dies used in making Square Nuts in Machine of the Type shown in Fig. 32

When this method is used, the die is drawn by the heat remaining in the body and is thus tempered, and the life of the die increased.

The second kind of vanadium tool steel recommended has the following analysis: Carbon, 0.65 to 0.75 per cent; manganese, 0.40 to 0.60 per cent; vanadium, not less than 0.16 per cent; silicon, not more than 0.20 per cent. The heat-treatment for this steel should be as follows: Heat to 1525 degrees F. and quench in water with the face of the die only submerged.

The length of life of vanadium steel dies is stated to be about six times the life of dies made from ordinary high-carbon tool steel.

The cut-off tool *c* is generally made from ordinary carbon tool steel, hardened and drawn. Some attempts have been made to use high-speed steel for this tool, but as this material is rather expensive, and as this particular tool wears away very rapidly, a cheaper brand of

steel is generally adopted. The piercing tool *f* when made from "Rex A" high-speed steel has been found very satisfactory for hot punching. The crowning tool *e* and wad extractor *d* can be made from ordinary carbon tool steel, hardened and drawn.

In order that the tools in a center-feed hot-pressed nut machine may work freely, it is necessary to provide a certain amount of clearance, especially between the cut-off tool, crowning tool and dies. On nuts from ½ to 2 inches in diameter (this is the size of the bolt for which the nut is used), 1/64 inch clearance is allowed. On sizes smaller than ½ inch, 0.010 inch clearance is allowed, whereas for tools used in making nuts larger than 2 inches, a clearance of from 0.020 to 0.060 inch is provided. The hole formed by the junction of the two halves of the dies is made prefectly straight, but the piercing tool is slightly tapered—being smaller at the front end. This enables it to withdraw more easily from the hole in the nut, and also increases its life. It is evident, of course, that after the hole is punched in the nut, the chilling effect of the dies (which are kept cool by water flowing over them) tends to "freeze" the nut onto the piercing tool, but the slight taper on the piercing tool prevents this.

There is no allowance made in the hole of the nut to provide for shrinkage, as the holes regularly punched in nuts are made considerably larger than the root diameter of the threads on the tap. The nuts can then be more easily tapped, and the percentage of tap breakages is reduced.

In Fig. 43 is shown the shape of the dies used for making square nuts in a center-feed hot-pressed nut machine. It will be seen that these dies are made in four pieces, and it is possible to raise or lower the outside blocks *A* and *B*, so that new cutting edges are secured. In addition to this the top and bottom dies *C* and *D* can be reserved, and also the two side pieces, thus giving long life for one redressing of the dies. As a rule, this type of dies is made from ordinary crucible tool steel containing from 0.90 to 1.00 per cent carbon, hardened and drawn, and ground all over.

Dies and Tools Used in Hot-forged Nut Machines

The four hammers used in the hot-forged nut machines are made from rectangular blocks of steel, shaped as shown in Fig. 40. The rear, front and stationary hammers are made wider than the nut, but of approximately the same thickness, and the front and rear hammers are rounded on the forward corners, to facilitate the insertion of the nut. The side hammer, which carries the nut into the "box-shaped impression" formed by all four hammers, is of the same width and thickness as the nut. The crowner, flatter tool and the four hammer blocks are all made from ordinary crucible steel, hardened and drawn, whereas the shearing tool and piercing punch and die are usually made from high-speed steel. The brand of steel known as "Rex A" has been found very satisfactory for this

TABLE III. PROPORTIONS OF U. S. STANDARD AND MANUFACTURERS' STANDARD HEXAGON AND SQUARE NUTS AND SIZES OF RECTANGULAR STOCK REQUIRED TO PRODUCE THEM. (See notation on illustration on opposite page.)

United States Standard									
Dia. of Bolt	Dimensions in Inches								
	A	B	C	D	E	F	G	H	I
1/4	1/4	1/2	[illegible]	[illegible]	[illegible]	1/4	1/2	[illegible]	[illegible]
5/16	5/16	19/32	[illegible]	[illegible]	[illegible]	5/16	19/32	[illegible]	[illegible]
3/8	3/8	11/16	[illegible]	[illegible]	[illegible]	3/8	11/16	[illegible]	[illegible]
7/16	7/16	25/32	[illegible]	[illegible]	[illegible]	7/16	25/32	[illegible]	[illegible]
1/2	1/2	7/8	[illegible]	[illegible]	[illegible]	1/2	7/8	[illegible]	[illegible]
9/16	9/16	31/32	[illegible]	[illegible]	[illegible]	9/16	31/32	[illegible]	[illegible]
5/8	5/8	1 1/16	[illegible]	[illegible]	1	5/8	1 1/16	[illegible]	1
3/4	3/4	1 1/4	[illegible]	[illegible]	1 3/16	3/4	1 1/4	[illegible]	1 3/16
7/8	7/8	1 7/16	[illegible]	[illegible]	1 3/8	7/8	1 7/16	[illegible]	1 3/8
1	1	1 5/8	[illegible]	1 1/16	1 9/16	1	1 5/8	1 1/16	1 9/16
1 1/8	1 1/8	1 13/16	[illegible]	1 3/16	1 3/4	1 1/8	1 13/16	1 3/16	1 3/4
1 1/4	1 1/4	2	1 3/32	1 3/8	1 [illegible]	1 1/4	2	1 3/8	1 [illegible]
1 3/8	1 3/8	2 3/16	1 7/32	1 1/2	2 1/16	1 3/8	2 3/16	1 1/2	2 1/16
1 1/2	1 1/2	2 3/8	1 [illegible]	1 5/8	2 1/4	1 1/2	2 3/8	1 5/8	2 1/4
1 5/8	1 5/8	2 9/16	1 [illegible]	1 3/4	2 7/16	1 5/8	2 9/16	1 3/4	2 7/16
1 3/4	1 3/4	2 3/4	1 [illegible]	1 7/8	2 5/8	1 3/4	2 3/4	1 7/8	2 5/8
1 7/8	1 7/8	2 15/16	1 [illegible]	2	2 13/16	1 7/8	2 15/16	2	2 13/16
2	2	3 1/8	1 [illegible]	2 1/8	3	2	3 1/8	2 1/8	3
2 1/4	2 1/4	3 1/2	2 [illegible]	2 3/8	3 3/8	2 1/4	3 1/2	2 3/8	3 3/8
2 1/2	2 1/2	3 7/8	2 [illegible]	2 [illegible]	3 3/4	2 1/2	3 7/8	2 5/8	3 3/4
2 3/4	2 3/4	4 1/4	2 [illegible]	2 [illegible]	4 1/8	2 3/4	4 1/4	2 7/8	4 1/8
3	3	4 5/8	2 [illegible]	3 1/8	4 1/2	3	4 5/8	3 1/8	4 1/2
3 1/4	3 1/4	5	2 [illegible]	3 3/8	4 7/8	3 1/4	5	3 3/8	4 7/8
3 1/2	3 1/2	5 3/8	3 [illegible]	3 5/8	5 1/4	3 1/2	5 3/8	3 5/8	5 1/4
3 3/4	3 3/4	5 3/4	3 [illegible]	3 7/8	5 5/8	3 3/4	5 3/4	3 7/8	5 5/8
4	4	6 1/8	3 1/2	4 1/8	6	4	6 1/8	4 1/8	6

Manufacturers' Standard									
Dia. of Bolt	Dimensions in Inches								
	A	B	C	D	E	F	G	H	I
1/4	1/4	1/2	[illegible]	[illegible]	[illegible]	1/4	1/2	[illegible]	[illegible]
5/16	5/16	5/8	[illegible]	[illegible]	[illegible]	5/16	5/8	[illegible]	[illegible]
3/8	3/8	3/4	[illegible]	[illegible]	[illegible]	3/8	3/4	[illegible]	[illegible]
7/16	7/16	7/8	[illegible]	[illegible]	[illegible]	7/16	7/8	[illegible]	[illegible]
1/2	1/2	1	[illegible]	[illegible]	[illegible]	1/2	1	[illegible]	[illegible]
9/16	9/16	1 1/8	[illegible]	[illegible]	1 1/16	9/16	1 1/8	[illegible]	1 1/16
5/8	5/8	1 1/4	[illegible]	[illegible]	1 3/16	5/8	1 1/4	[illegible]	1 [illegible]
3/4	3/4	1 3/8	[illegible]	[illegible]	1 5/16	3/4	1 1/2	[illegible]	1 [illegible]
7/8	7/8	1 1/2	[illegible]	[illegible]	1 7/16	7/8	1 3/4	[illegible]	1 [illegible]
1	1	1 3/4	[illegible]	1 1/16	1 11/16	1	2	1 1/16	1 [illegible]
1 1/8	1 1/8	2	[illegible]	1 3/16	1 13/16	1 1/8	2 1/8	1 3/16	2 1/16
1 1/4	1 1/4	2 1/8	1 [illegible]	1 1/4	2 1/16	1 1/4	2 1/4	1 [illegible]	2 1/8
1 3/8	1 3/8	2 1/4	1 3/16	1 3/8	2 1/4	1 3/8	2 1/2	1 [illegible]	2 1/4
1 1/2	1 1/2	2 5/8	1 5/16	1 [illegible]	2 3/8	1 1/2	3	1 [illegible]	2 [illegible]
1 5/8	1 5/8	3	1 7/16	1 [illegible]	2 [illegible]	1 5/8	3 1/4	1 [illegible]	3 [illegible]
1 3/4	1 3/4	3 1/8	1 9/16	2	[illegible]	1 3/4	3 1/2	2	3 [illegible]
1 7/8	1 7/8	3 1/2	1 11/16	2 1/8	3	1 7/8	3 3/4	2 1/8	3 [illegible]
2	2	[illegible]	1 13/16	2 1/4	3 [illegible]	2	4	2 1/4	3 [illegible]
2 1/4	2 1/4	3 3/4	2	2 3/8	3 [illegible]	2 1/4	4 1/4	2 3/8	4 [illegible]
2 1/2	2 1/2	4 1/8	2 1/4	2 5/8	4 1/8	2 1/2	4 1/2	2 5/8	4 [illegible]
2 3/4	2 3/4	4 1/2	2 7/16	2 7/8	4 [illegible]	2 3/4	4 3/4	2 7/8	4 [illegible]
3	3	4 7/8	2 [illegible]	3 1/8	4 [illegible]	3	5	3 1/8	4 [illegible]
	..	..	.	..	.	.	..	.	.
	..			..		..	..	..	.
			.	.	.	.	..	.	..
			..	.	..		..	.	.

purpose. The tools used in the hot-forged nut machine do not wear out nearly so quickly as those used in the hot-pressed type of machine, owing to the fact that there is not the same scraping action against the surfaces of the tools.

Sizes of Rectangular Stock Used in Making Square and Hexagon Nuts

In making nuts in center-feed hot-pressed nut machines of the types shown in Figs. 34 and 35, rectangular bar stock as shown in Fig. 37 is used. To allow for upsetting the stock slightly and pressing it into the desired shape, a rectangular bar is used which is slightly thicker than the finished nut, and slightly less in width than the diameter of the nut across the flats. As explained in a previous paragraph, in order to produce a perfectly shaped nut it is necessary to waste a certain amount of stock as indicated at *a* and *b* in Fig. 44. The amount of stock wasted depends upon the size of the nut and to a

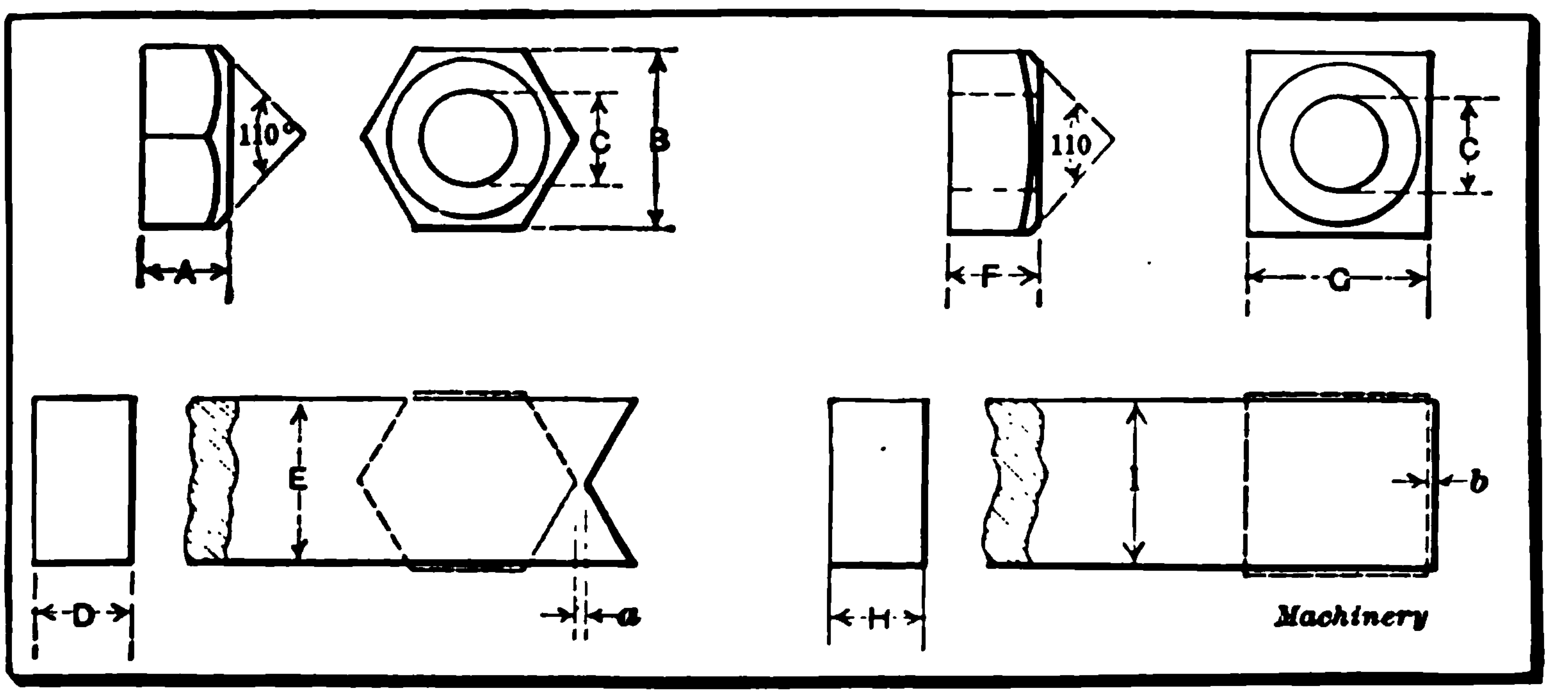


Fig. 44. Proportions of Standard Hexagon and Square Nuts; see Table on Opposite Page

slight extent upon the temperature at which the bar is being worked.

In producing a hexagon nut, only the front triangular corner is rounded (owing to the drawing over of the hot metal), whereas on a square nut, the entire front corner of the nut is rounded. A considerable saving of metal can be effected by turning the bar after each stroke of the machine, thus presenting opposite faces of the bar to the dies, as was previously explained. This can easily be done in making the smaller size of nuts where the bar does not exceed 40 to 80 pounds in weight. For large nuts, instead of turning the bar, a small amount of stock is wasted, as indicated at *a* and *b* in Fig. 44, which varies from 1/16 to ¼ inch, depending upon the size of the nut.

The hot-forged type of nut-making machine shown in Fig. 39 has the advantage over the center-feed hot-pressed machine of not wasting any stock. The hot-forged nut machine, however, is only suitable for the manufacture of square nuts, and is only used where this type of nut is made in large quantities.

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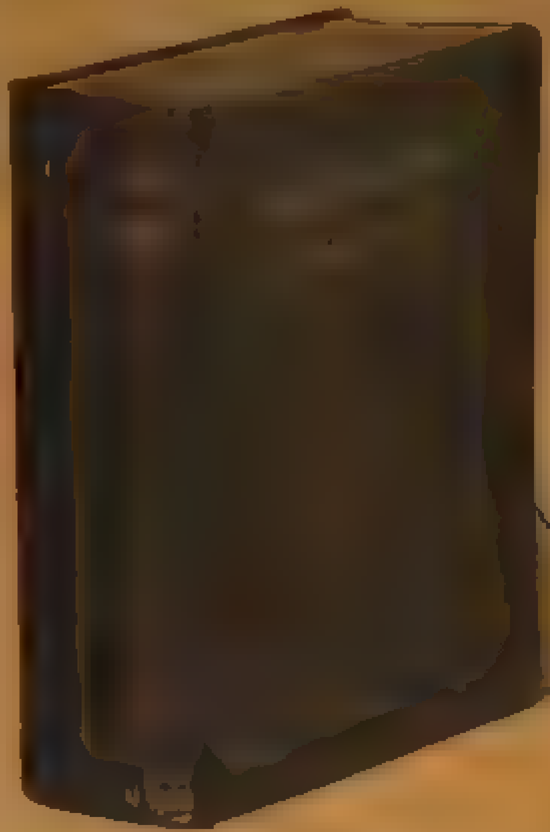

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MACHINE FORGING

By DOUGLAS T. HAMILTON

CONTENTS

CHAPTER I

MACHINE FORGING DIES AND METHODS

Possibly the greatest advance made of late years in forging is the application of machine methods to the production of engine and machine parts. It is now possible to forge many parts from steel and wrought iron, which a few years ago could only be made from castings. This means a great saving of time and expense, as not only are machine forged parts much more rapidly made than those made from cast iron or steel castings, but they also cost considerably less to manufacture in large quantities. In the following, interesting examples of different types of upsets, bending and forming operations, etc., will be illustrated and described, together with a general description of the dies and tools used. This will give an idea of the remarkable possibilities of the upsetting and forging machine in its present-day development.

The Upsetting and Forging Machine

The upsetting and forging machine might be considered to a certain extent as a further development of the bolt and rivet making machine, which was originated almost a century ago; but forging machines are built much heavier than bolt and rivet machines and are designed especially to meet the demands in the production of difficult-shaped and heavy forgings. For the heavier types of machines, the base or main frame, as a rule, is made from one solid steel casting.

A typical upsetting and forging machine designed for heavy service is shown in Fig. 1. The bed of this machine is made from one solid casting of semi-steel. In order to provide against breakage caused by accidentally placing work between the dies, upsetting and forging machines are usually furnished with various safety devices to prevent serious damage to the machine. The safety device in this machine consists of a toggle-joint mechanism for operating the movable gripping-die slide. The gripping die slide *A*, Fig. 1, is operated by two cams *B* and *C* on the main crankshaft *D*. Cam *B* serves to close the dies which grip the work; cam *C* operates the opening mechanism for the dies. These cams are in contact with chilled cast-iron rolls *E* and *F* carried in the toggle slide *G*. The automatic grip relief is controlled by the by-pass toggle *H* and heavy coil spring *I*. This toggle does not come into play until the strain is such that it would cause damage to the working mechanism of the machine, or in other words until the maximum power required to hold the movable die from sp
is attained. The relief resets automatically on the b
machine, thus making a second blow possible with

Some idea of the gripping pressure exerted b

anism operates is indicated in Fig. 2. This piece, which has been flattened between the opposing faces of the gripping dies, is a 2-inch round bar of 0.10 to 0.15 per cent carbon steel, 9⅝ inches long. The flattened portion is 3⅝ inches wide by 5 inches long and 23/32 inch thick. The piece, of course, was heated to a forging temperature before

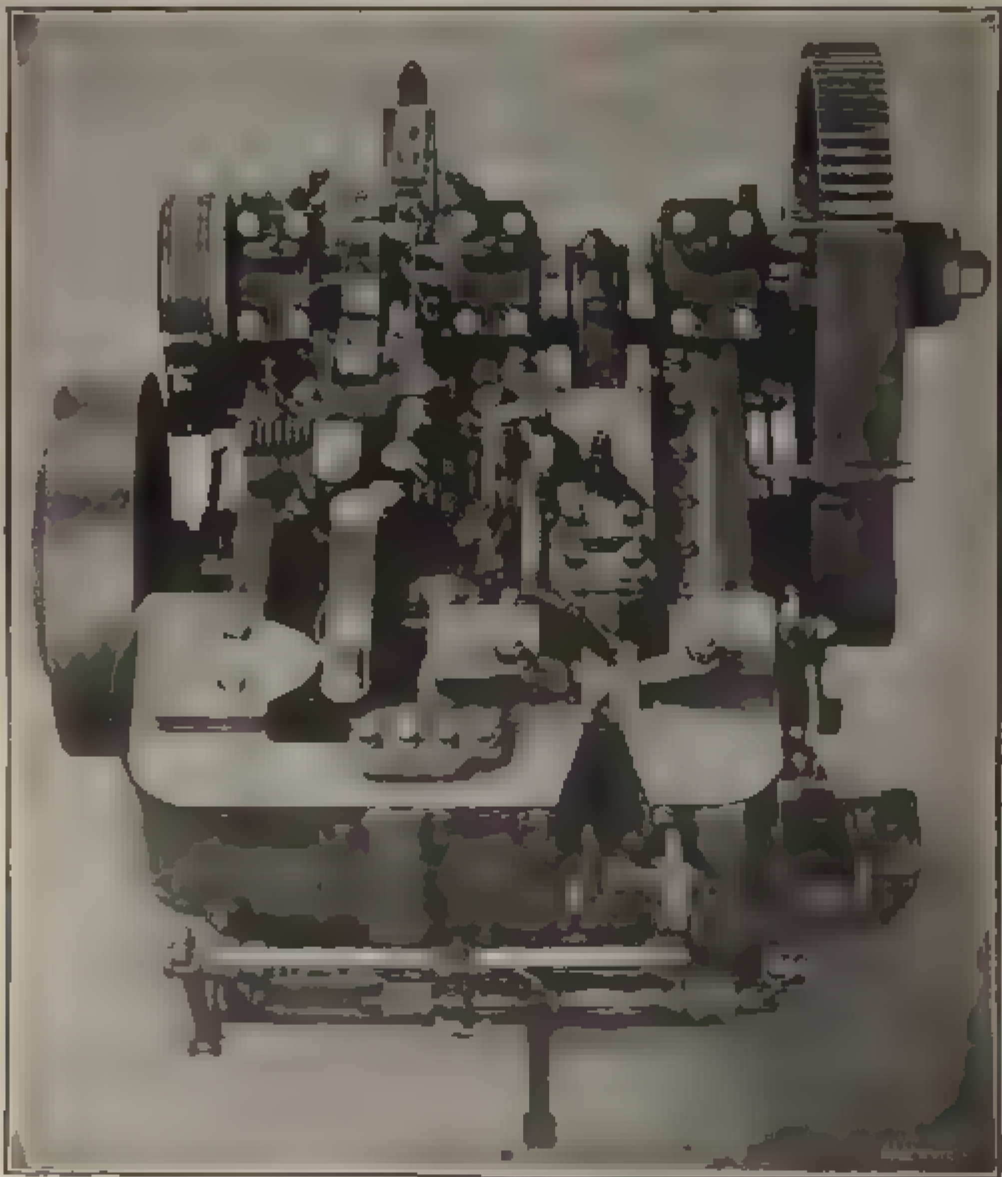

Fig. 1. "National" Upsetting and Forging Machine having a Safety Relief Mechanism for operating the Gripping Dies

being placed between the opposing faces of the dies and was flattened to the condition shown in one squeeze. This illustrates a feature peculiar to this type of machine in that it can be used for squeezing or swaging operations, these being carried on between the opposing faces of the gripping dies. In many cases this allows work to be handled that is generally formed or flattened by the side shear *J*, which is operated from the movable die slide, being a continued arm of the same casting. As a rule, the side shear is used for cutting off stock, and is also sometimes used for bending operations, suitable dies or cutting tools for this purpose being held in the movable slide *J* and stationary bracket *K*.

Another type of upsetting and forging machine in which the working mechanism of the machine is protected from serious injury in a differ-

ent manner, is shown in Fig. 3. In this machine the safety device consists of a bolt A connecting the die slide B and the slide C operating it. When any foreign body intercepts the gripping dies, the bolt A is sheared off, thus providing for a positive grip and at the same time furnishing a safety device that protects the working mechanism of the machine against serious injury

Fig. 2. Extent to which a Bar is flattened between Gripping Dies of "National" Forging Machine before Relief operates

A good example of an upset forging operation which can be handled successfully in an upsetting and forging machine, is the castellated nut shown at A in Fig. 4. This type of nut is produced practically without waste of stock in from two to three blows The gripping dies and tools used are shown in Fig 4, and also in detail in Fig. 5, where the construction of the tools can be more clearly seen. Referring to the latter illustration, it will be noticed that the dies C and D are made in two pieces. This is done

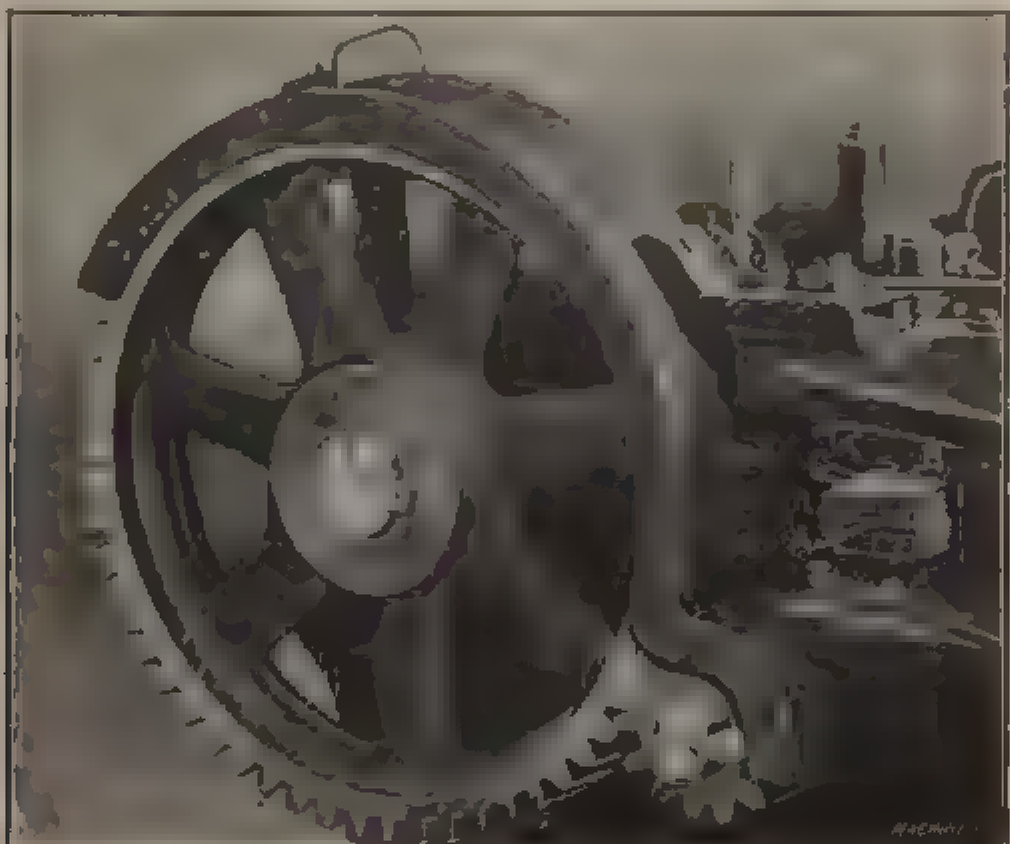

Fig. 3. Ajax Upsetting and Forging Machine showing Safety or Shear Bolt, providing a Safety Relief for the Gripping Dies

in order to facilitate the machining operations, and in many cases it enables the dies to be made much cheaper because of the simplicity in construction. These dies are made from scrap driving-

axle steel which contains about 0.60 per cent carbon, and are hardened in the usual manner, the temper being drawn to a light straw color.

The plunger *E* which upsets the end of the bar into the lower impression in the dies, is made in three parts; this facilitates its construction and the method of manufacture. The body is made from a piece of soft machine steel, on the front end of which a hardened bushing *F* is held by a pin. The inside of this bushing is of a hexagon shape to form the sides of the nut. Screwed into the body of the punch is a former *G* which is machined to such shape that six "wings," as shown, are formed around its periphery, these producing the castellated grooves in the head of the nut. The former *G* is pointed, and rough-forms the hole in the nut. The top punch which is used for completely punching the hole in the nut and at the same time severing it from the bar is also made from a machine steel body *H* into which is screwed a hardened steel punch *I*, this being prevented from loosening by a pin driven through it.

Fig. 4. Dies and Tools used in making a Castellated Nut in an Ajax Forging Machine in the L. S. & M. S. Railway Shops at Collinwood, Ohio

The method of producing a hexagon castellated nut in a forging machine is as follows: A bar of the required size (which must not exceed the root diameter of the thread in the finished nut) is heated in the furnace to a temperature of from 1400 to 1600 degrees F., depending upon the material, and is then brought to the forging machine and placed in the lower impression of the gripping dies. Then as the machine is operated, the lower plunger advances, upsetting the end of the bar and forming the excess metal into a nut of the required shape. The bar is now quickly removed from the lower impression, placed in the upper impression, and the machine again operated; whereupon the top plunger advances, completing the hole in the nut and attaching the metal thus removed to the end of the bar. These two operations are

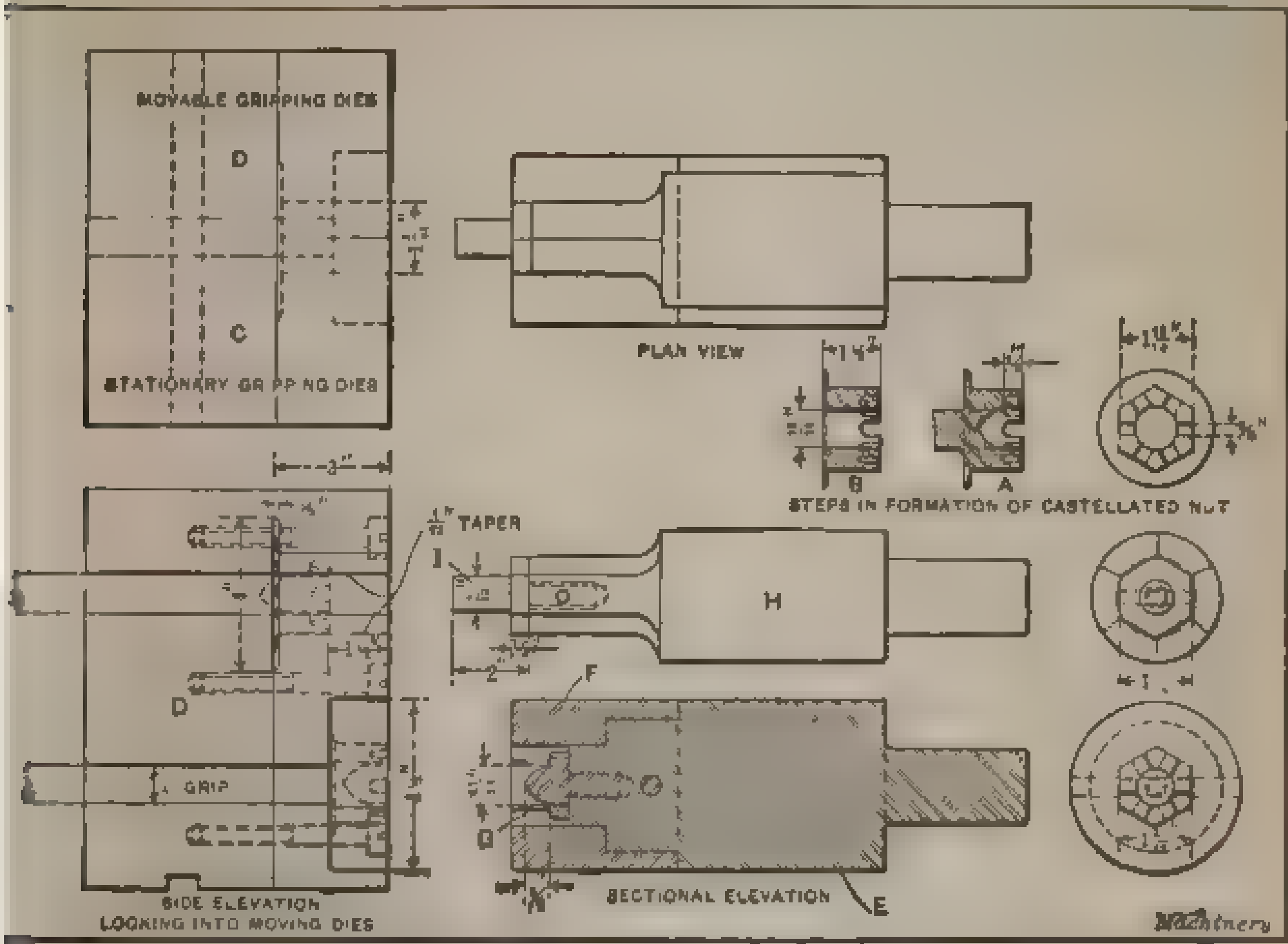

Fig. 5. Details of the Dies and Tools used for making the Castellated Nut shown in Fig. 4

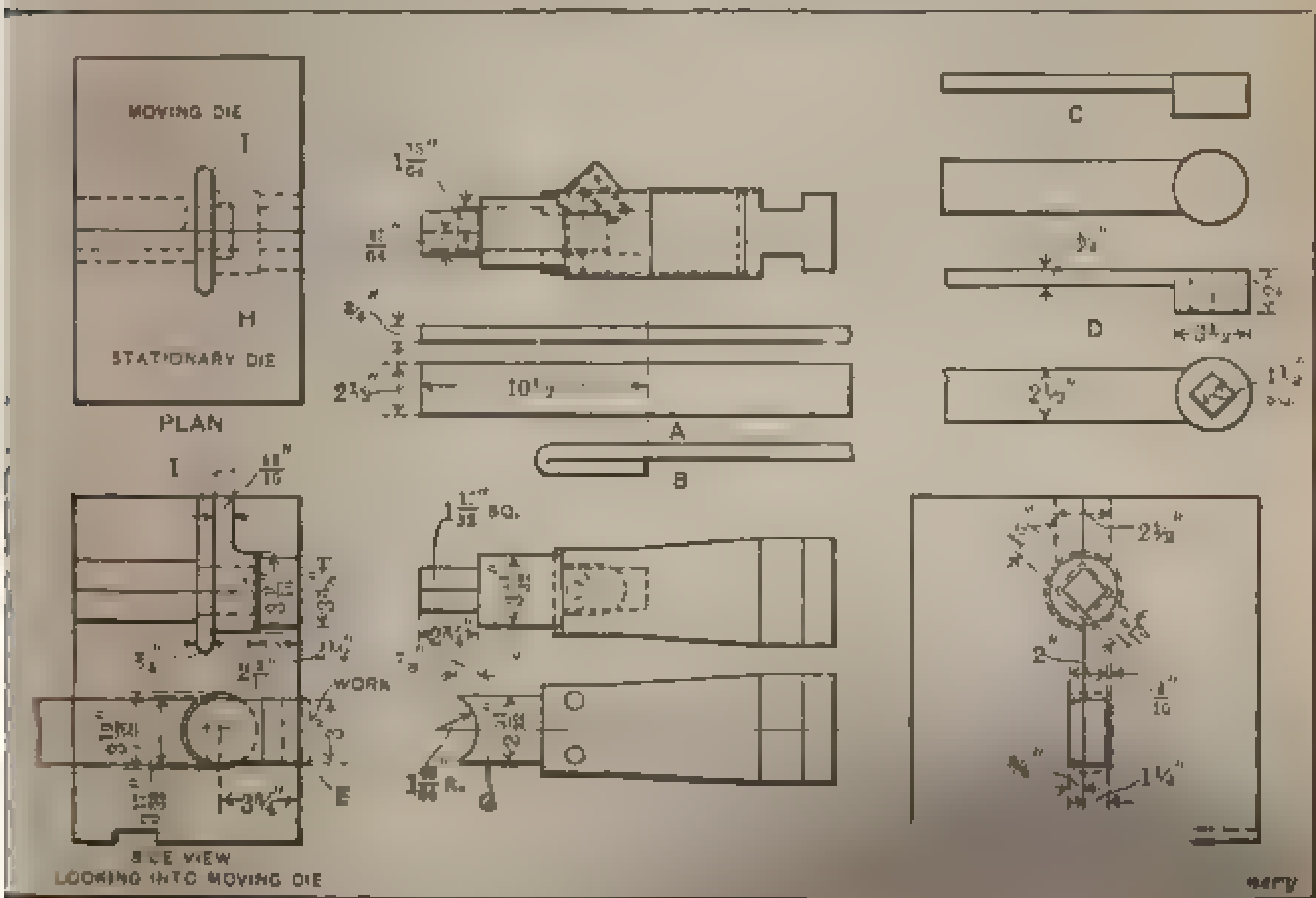

Fig. 6. Dies and Tools used in making a Lo

indicated at *A* and *B* in the illustration. This interesting method of making castellated nuts is used in the Collinwood shops of the L. S. & M. S. Railway. The only material wasted in the production of a castellated nut of this character is the slight excess of stock formed into a fin, which must be removed, of course, in a subsequent operation.

Another interesting example of castellated nut forging in which the excess metal is used in the formation of a washer on the nut and thus eliminates all waste of material, is shown in Fig. 7. The construction of the tools here

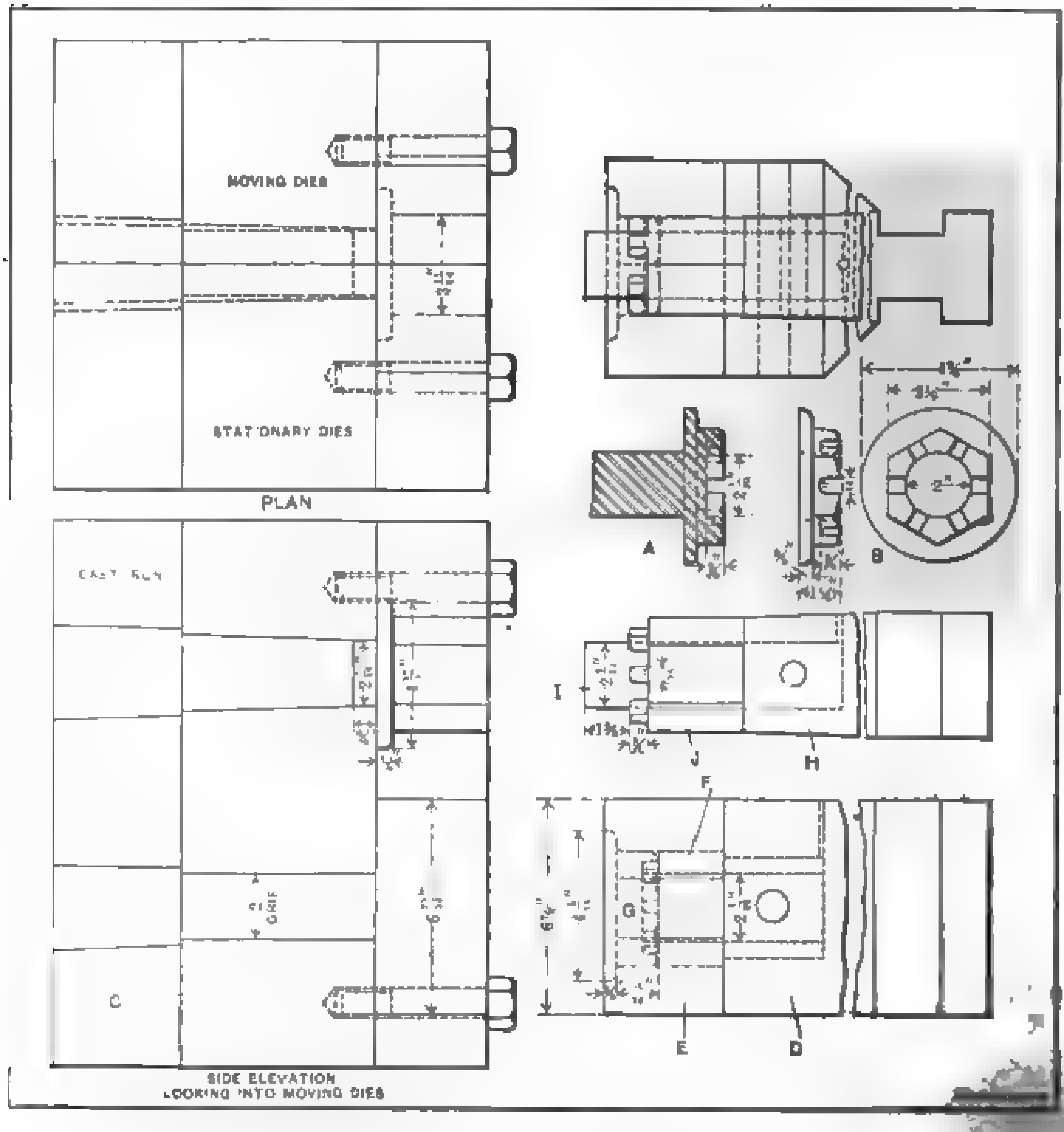

Fig. 7. Dies and Tools used for making a Combination Washer and Castellated Nut which is produced without any Waste of Stock

illustrated is almost identical with that shown in Figs. 4 and 5 wi ception of the punches and also the utilization of a cast-iron b partly completing the construction of the gripping dies. The part ping dies which is made from cast iron is not used as a gripping s

hence does not need to be made from steel to provide for wear. The lower punch *D* is in this case made from machine steel and is provided with a tool-steel head *E* which is bored out and formed to a hexagon shape. Inserted in this is a sleeve *F* for forming the castellated portion of the nut. A punch *G* rough-forms the hole in the nut. The upper plunger *H* carries a punch *I* which completely forms the hole in the

Fig. 8. Dies and Tools used in making an Enormous Upset in a 6-inch Ajax Universal Forging Machine

nut by punching the bar back, and by means of the castellated washer *J* finish-forms the castellated grooves in the nut. The steps followed in the production of this combination castellated nut and washer are shown at *A* and *B* in the illustration. A 2-inch bar of wrought iron is used, and it requires a length of 4 inches to form the nut and washer.

Dies and Tools Used for Making a Locomotive Trailer Pin

The locomotive trailer pin shown at *A* in Fig 8 represents about the maximum amount of upset which can be satisfactorily made in a forging machine, and in fact, is much greater than that usually recommended. This example which is supposed to be the largest upset ever made by machine methods was accomplished in the Chicago shops of the C. & N. W Railway, on a 6-inch Ajax universal forging machine This trailer pin [illegible] from a 3-inch round wrought-iron bar, 26

inches long, and an excess amount of stock equal to 10¾ inches in length is put into the upset in one blow. The dimensions of the upset square flange are 7⅞ inches across the flats and 10 5/16 inches across the corners, by 1⅜ inch thick. The circular flange is 5⅞ inches in diameter by ⅝ inch long. After the work is given the first blow with the plunger *B*, it is reheated and the work is again placed between the gripping dies *C*, only one of which is shown. The machine is again operated and the part given another blow which serves to close up the

Fig 9 Three Steps in the Formation of Ladder Treads for Freight Cars, accomplished in a "National" Forging Machine

texture of the steel and eliminates the defects caused by the structure of the steel pulling apart during the upsetting operation This large upset gives an idea of some of the possibilities of machine forging in making engine parts, etc.

Bending and Forming Operations

The making of ladder treads for freight cars is a good example of bending and forming operations that can be handled successfully in the upsetting and forging machine. Fig. 9 shows three of the steps in the production of a ladder tread which is completed to the shape shown at *C* in five operations.

The dies and tools used for forming the feet of the ladder tread are illustrated in Fig. 10. The first operation is indicated at *A* and consists in cutting off a bar of ¾ inch iron to the required length. This is heated on one end, placed in the lower impression in the gripping dies *G* and *H* and given a blow by the plunger *I* which forms the end of the rod into the shape shown at *B*. In this operation, the stock is

upset just far enough so that it will not buckle in front of the dies.

The second operation bends and forms the stock back into a solid forging as indicated at *C*, this being accomplished in the second impression in the gripping dies by plunger *J*. The final forging operation, the result of which is shown at *D*, completes the foot, the upper impressions in the dies being used for this purpose, these are made the exact shape of the foot, and the plunger *K* has a pin in it which punches the hole in the foot to within 1/16 inch of passing through the 9/16-inch stock. The final operations which are performed in a bulldozer or other bending machine consist in bending both ends of the tread to the required shape. This requires two operations, which are indicated

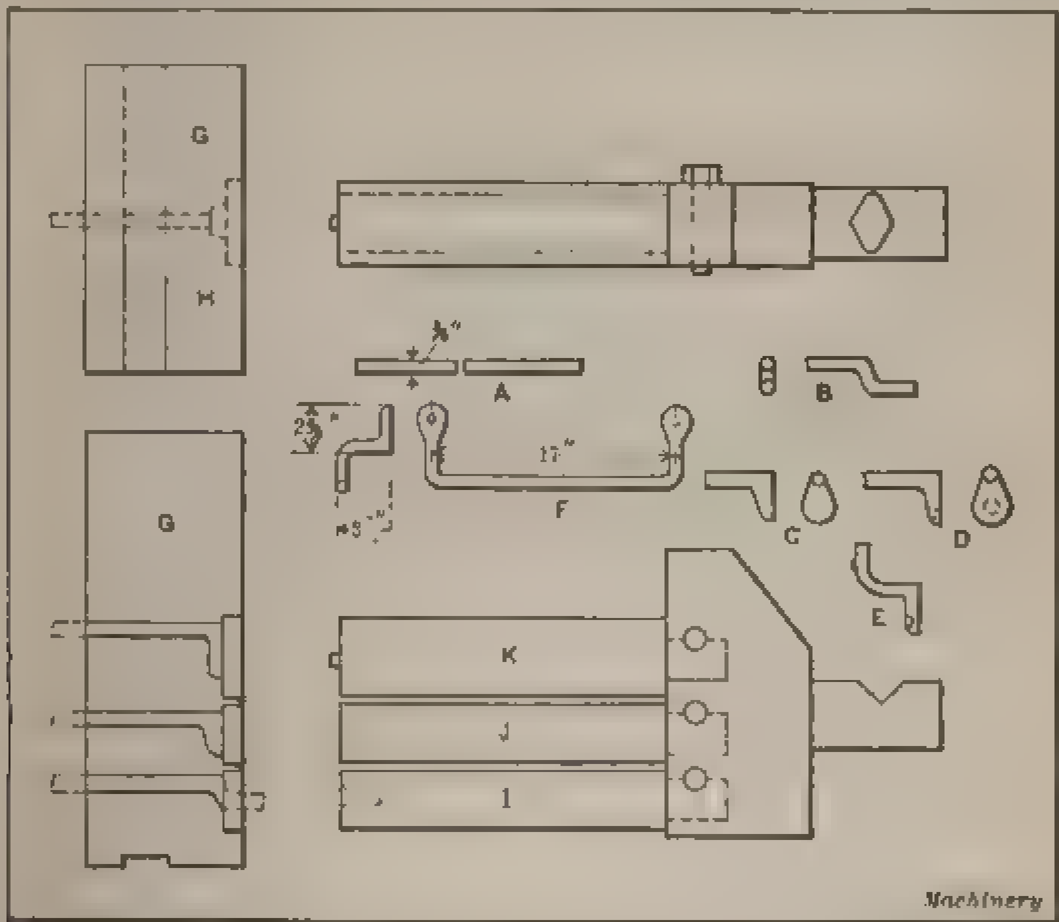

Fig. 10. Dies and Tools used in forming the Feet of Ladder Treads

at *E* and *F*, respectively Before the final bending, the forging is taken to an emery wheel to remove the burrs formed when forging the feet.

The eye-bolt shown in two stages of its formation, at *A* and *B* in Fig. 11, is another example of a bending and forming operation accomplished in a forging machine. This eye-bolt is made from a 1⅜-inch round wrought iron bar, and is completed in two blows in a 3-inch Ajax forging machine, using the dies and tools illustrated. The construction of the gripping dies is rather unusual and interesting The lower impression in the dies consists of two movable members *C* which slide on four rods *D* and are provided with tongues *E* which fit in corresponding grooves in ᵗʰ ˡe and stationary gripping dies. The pins, of course, act as ˡding these sliding members *C* in the gripping dies. ut against the adjustable lock nuts *F* by

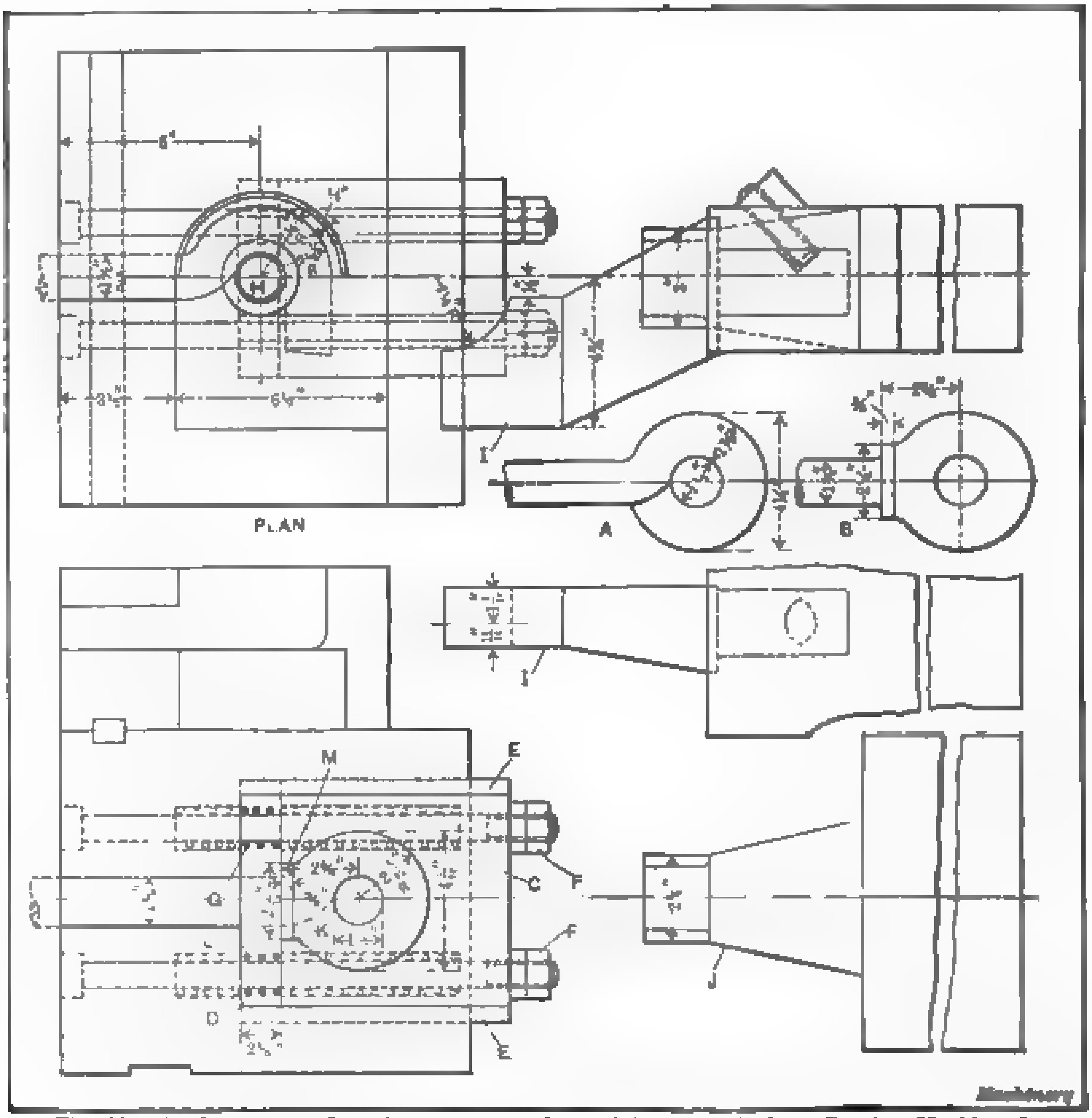

Fig. 11. An Interesting Set of Dies and Tools used in a 3-inch Ajax Forging Machine for forming Eye-bolts in Two Blows

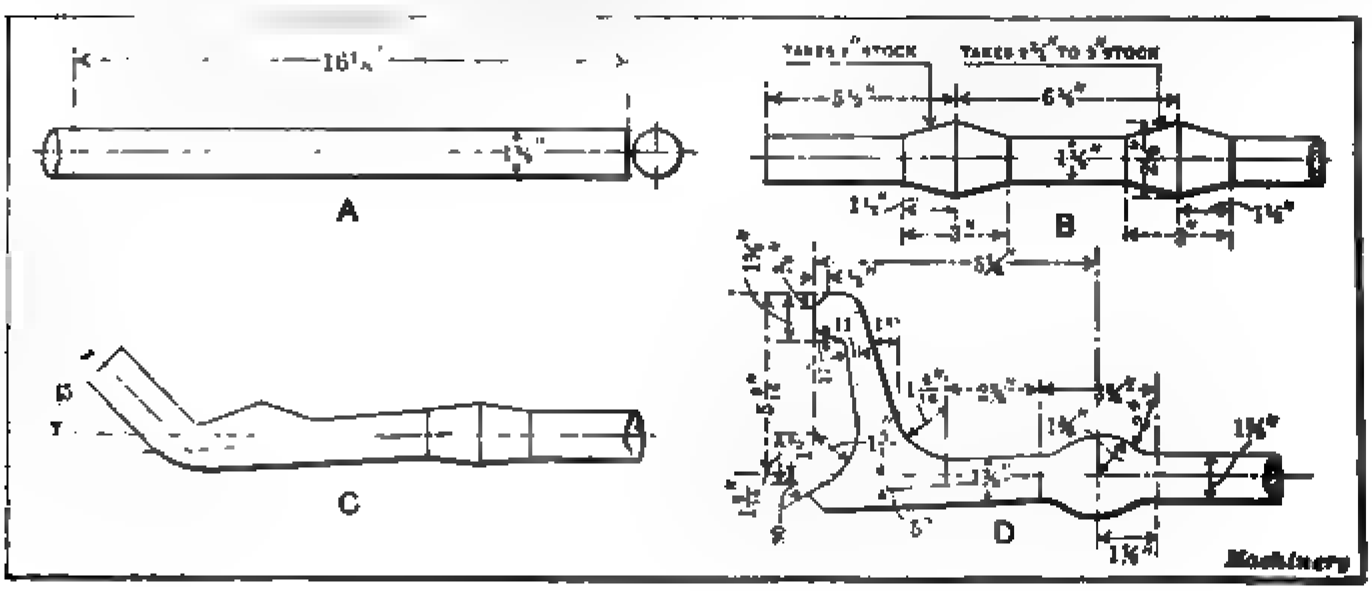

Fig. 12. Sequence of Operations on Ford Front Axle accomplished in "National" $3\frac{1}{2}$-inch Forging Machine

The method of operation is as follows: The stock is first heated for a portion of its length to the correct temperature, then placed in the upper impression of the stationary die, being located in the correct endwise position by the stop of the machine. The machine is then operated and when the movable die closes on the work, it grips it and at the same time forces the heated end of the stock around pin *H* held in the stationary die. Just as soon as the dies close tightly on the work, punch *I* comes in contact with the bent end of the bar and forms it around the pin *H*, bending the work into the shape shown at *A*. The dies now open and the work is removed and placed on the pin forming the center portion of the impression in the blocks *C*. The

Fig 13. Dies and Tools used for forming a Driver Brake Adjusting Rod Block in a 5-inch Ajax Forging Machine

machine is again operated and as the dies close, the ram *J* advances and forces the blocks *C* forward, carrying the "eye-end" of the work along with it.

Now as both parts of the bar—"eye-end" and body—are rigidly held in the gripping dies and movable blocks *C*, it is evident that the part of the bar at point *K* must be upset. The result of this displacement of the stock causes the formation of a shoulder on the bar at the base of the eye, formed by the circular impression *M* in the blocks *C*. The amount of stock required to form the boss at the base of the "eye" is governed by the position of the locknuts *F*. The ram *J* and gripping dies are made from steel castings. The four compression springs *G* are 10¾ inches long when extended, of ¼ inch pitch; 5/32-inch diameter wire is used, and the outside diameter of the spring is 1 3/16 inch

Dies and Tools for Forming a Driver Brake Adjusting Rod Block

A difficult forming operation accomplished in the forging machine is shown in Fig 13. The part *A* is a driver brake adjusting rod bloc^k

used on freight cars. It is made of wrought iron and is completed in two blows in a 5-inch Ajax forging machine. The method of procedure in making this piece is to first cut a piece of rectangular bar iron to the required length and then bend it into a U-shape in the bulldozer.

Fig. 14. A Heap of Finished Forged Coupler Pocket Filling Blocks

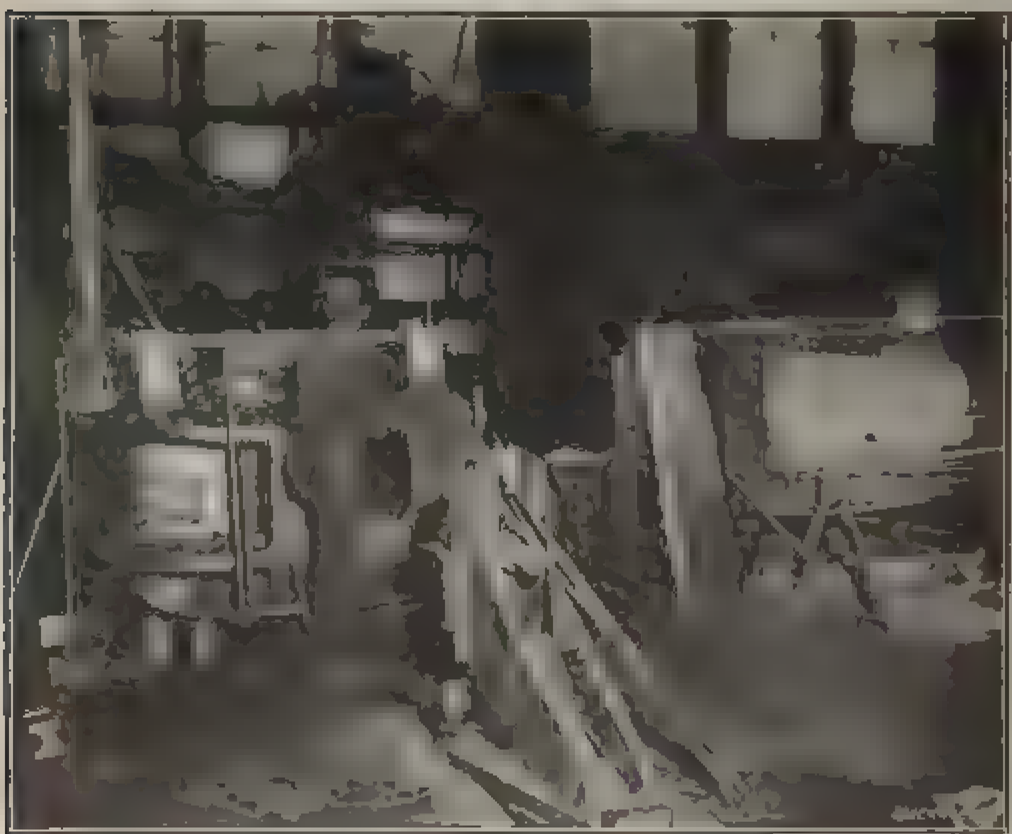

Fig. 15. 5-inch Ajax Forging Machine at Work in the Collinwood Shops of the L. S. & M. S. Railway, set up for making Coupler Pocket Filling Blocks for Freight Cars

It is then taken to the furnace where it is heated to the proper temperature, and a "porter" bar, about ¾ inch in diameter, is also heated. This is joined to the bent piece (which is to form the block) and the latter is placed between the gripping dies, the bar being used simply

as a means of handling. The dies shown at B and C are provided with half-round impressions shown at a and b through which the "porter" bar projects. As the machine is operated, the front end of plunger D cuts off the "porter" bar and forces the bent piece into the impressions in the gripping dies. While the piece is still held in the dies, the machine is again operated and the work given a second blow, this, of course, all being done in the one heat. The round-ended plug E at the end of the impression in the stationary die forms an impression in the end of the block and serves as a spot for a subsequent drilling operation. Work of this character demands a forging machine in which a rigid gripping mechanism is provided, if excessive fins on the work are to be avoided. The reason for this is that the plunger, in forcing the metal into the dies, has a tendency to separate them.

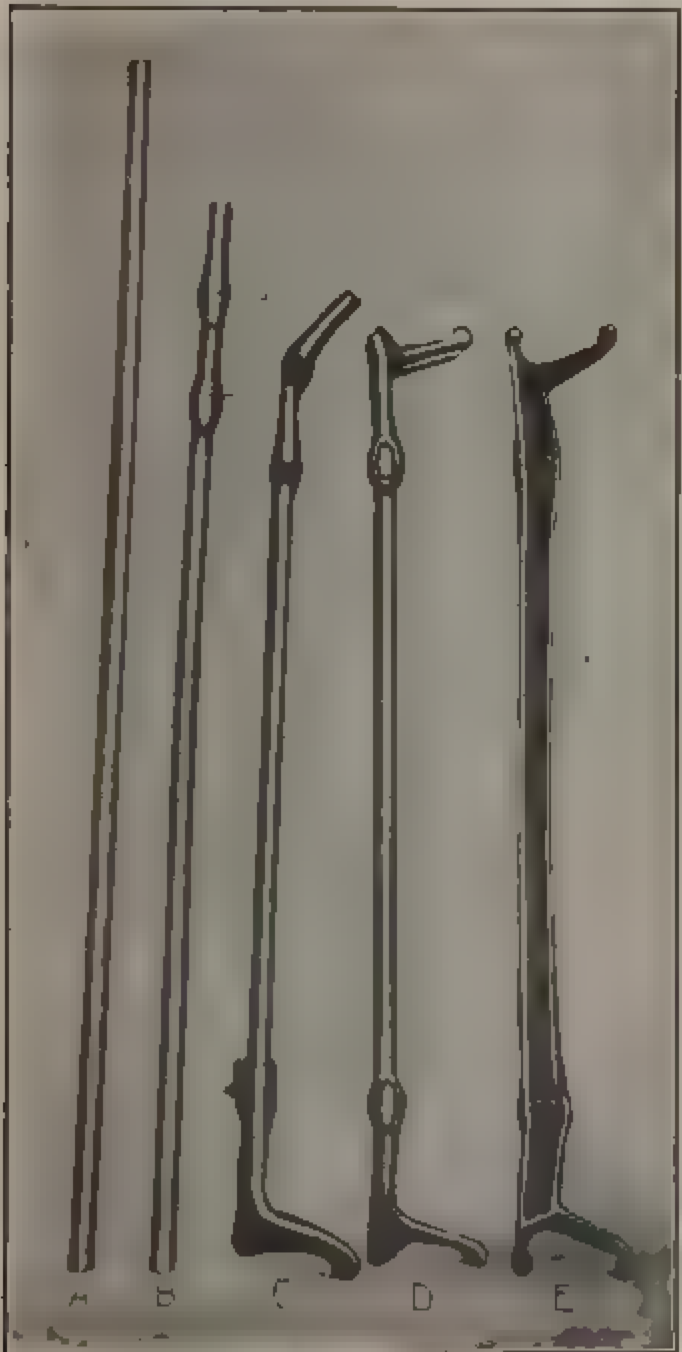

Fig. 16. Sequence of Forging Operations on the Ford Front Axle

Fig 14 shows a forging made in practically the same manner as that illustrated in Fig. 13. This part, a coupler pocket filling block, is used on freight cars, and is made from scrap arch bars cut up into pieces of the desired length. These pieces are first formed into a U-shape in a bulldozer and are then brought to the furnace shown to the right in Fig 15. Here they are heated to the desired temperature, then gripped with the tongs and placed on the shelf of the back stop A. The forging machine operator then lifts the piece from the shelf by means of a "porter" bar, and places it between the gripping dies, where the forging is given two blows and then thrown down in the sand to cool off. Fig. 14 gives some idea of how this coupler pocket filling block is produced. The piece of arch bar which has been formed to a U shape in the bulldozer still forms the end of the block, the sides or webs being formed by bending in the arch

and lapping up the open ends. This can easily be seen by referring to the piece *A* in the illustration, where the joint formed in this manner is clearly shown. The burrs formed on these pieces are removed in a subsequent operation.

Forging an Automobile Front Axle

The making of the Ford automobile front axle by forging machine methods is an excellent example of the general adaptability of the upsetting and forging machine to the manufacture of miscellaneous parts from carbon and alloy steels When used in conjunction with a steam hammer or bulldozer, there is practically no limit to the range of work which can be successfully handled. One of the most recent

Fig. 17. "National" 3½-inch Forging Machine used in accomplishing the Preliminary Operations on the Ford Front Axle

developments in forging-machine methods which should be of unusual interest to many manufacturers is the application of forging machines to the welding of machine and engine parts. This in many cases permits the utilization of scrap metal, thus converting practically valueless material into expensive machine parts. Some interesting forging operations employed in the production of the Ford front axle and other parts, will be described in the following:

In Fig 16 is shown a series of interesting operations performed in the 3½-inch "National" forging machine shown in Fig 17, the work being the front axle for the Ford automobile This front axle is made from a vanadium steel bar 1¾ inch in diameter by 67¾ inches long, as shown at *A* in Fig. 16 The first forging operation consists in form-

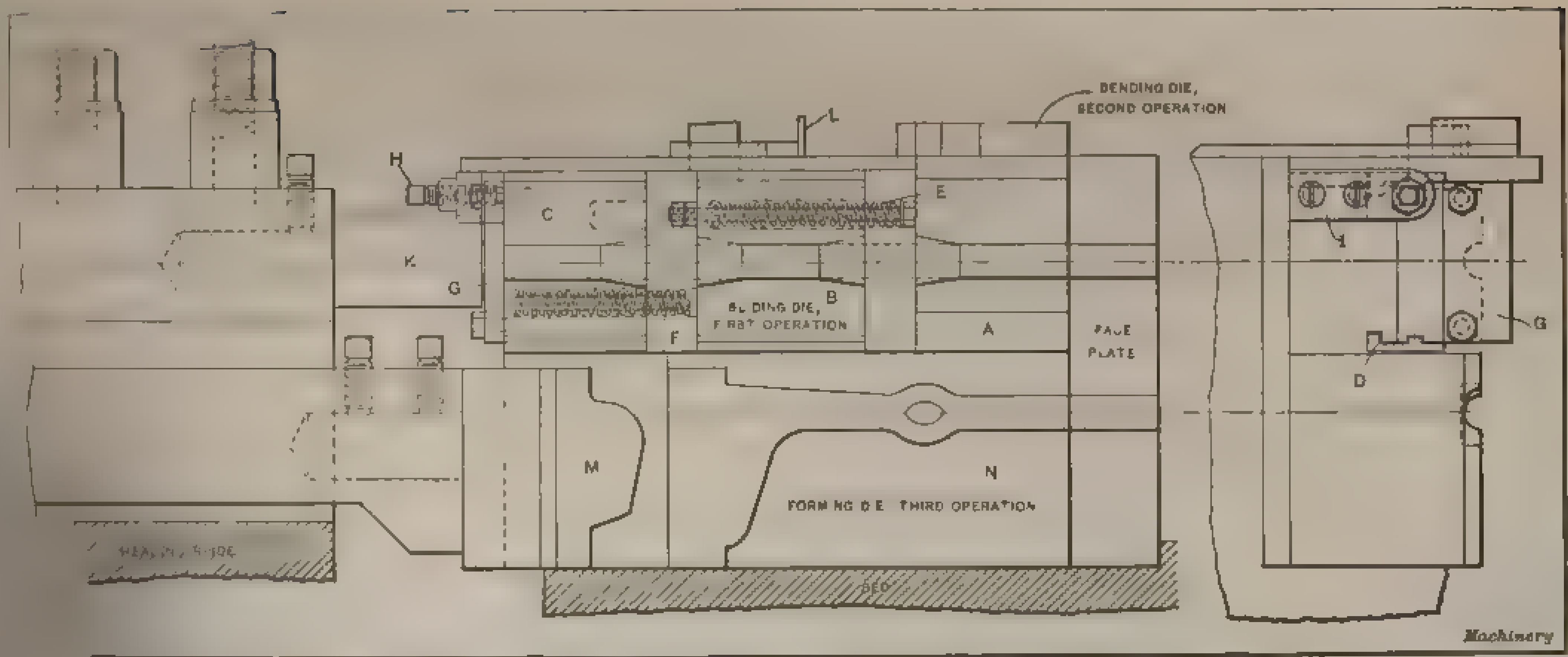

Fig. 18. Construction of Dies and Tools used in the "National" Forging Machine for making Ford Front Axle

two bulges a and b Both ends of the bar are formed s manner, but in separate heats This operation, n is also indicated at B in Fig 12, shortens the ends of the bar from a length of $16\frac{1}{8}$ inches to $13\frac{1}{2}$ inches, which means that $2\frac{5}{8}$ inches of stock is put into the bulges. The forging machine dies for performing this operation are shown in Fig 18, the bulging being accomplished in the top members In order to form both bulges at once it is necessary to have the top members of these dies constructed in such a manner that the blocks carrying the impressions are free to slide forward when acted upon by the plunger held in the ram of the machine.

As will be seen by referring to this illustration, one-half of the larger bulge is carried in block *A*, while the other half of the impression is carried in the sliding block *B*. In the opposite end of the sliding block *B* is provided one-half the impression for the smaller bulge, the other half being formed in the sliding block *C*. These sliding blocks *B* and *C* are held by tongue plates *D* to the main body of the top forging die in which they are free to slide. They are held in their outward positions by coil springs *E* and *F*. Coil spring *E* is carried on a stud held in sliding block *B*, while coil spring *F* is carried on a stud screwed into block *B* and fitting in a clearance hole in sliding block *C*. The stock, when heated to the correct temperature, is located in the proper posi-

Fig. 19. "Massillon" Steam Hammer used for bringing the Ford Front Axle to Final Shape

tion in the dies by block *G*, which is fastened by cap-screws to block *C*, and covers the hole in the dies as indicated in the end view. Block *C* is located in its proper "out" position by means of adjusting screw *H*, held in block *I*, fastened to the top member of the forging die.

The stock which has been heated for a distance of about 18 or 20 inches is placed in the impressions in the upper members of the stationary gripping dies. The machine is then operated; the gripping dies hold the work rigidly, while plunger *K* advances and forces sliding

block *C* forward until it is in contact with block *B*. The forward movement of the ram continues until block *B* is forced up against block *A*, when the ram recedes, the dies open, and the forging is removed. It is evident that as the work is held rigidly between the opposing faces of the gripping dies, the advance of these sliding members can only accomplish one result, which is to upset the excess metal and expand it into the impressions provided in the dies, thus forming the bulges.

The next operation on the front axle, which is indicated on the top of the axle at *C* in Fig. 16, and also at *C* in Fig. 12, consists in bending

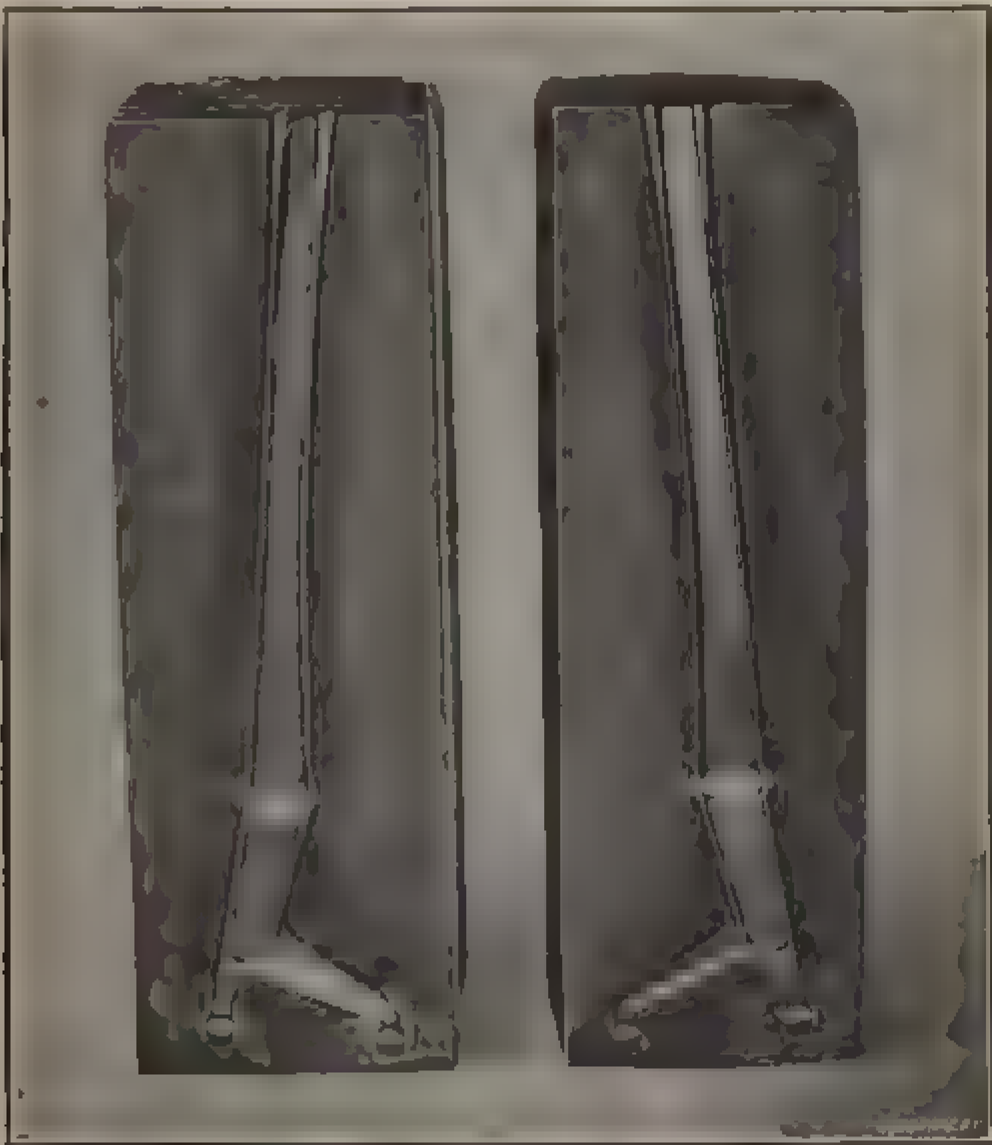

Fig. 20. Upper and Lower Dies used in Steam Hammer shown in Fig. 19 for finish-forming the Ford Front Axle

the end around in order to locate the material in the required position for forming the knuckles of the axle. This operation is handled in the dies shown in Fig. 18, that member which accomplishes the work being formed on the top face of the top members of the dies. The bar, which is still in its initial heat, is laid on top of the dies and in contact with the stop gage *L*. The machine is then operated, and as the dies close, the impressions formed on the projection of the top die twist the end of the bar around and form it to the desired shape

The bar is now placed in the furnace and again heated to the proper

temperature. Then it is brought to the forging machine and placed in the lower impression in the gripping die shown in Fig. 18. The forging machine is then operated, and as plunger *M* advances, it upsets and forces the work into the impressions in the lower gripping dies *N*, forming the front axle to the shape shown at *D* in Figs. 12 and 16. This completes the operations on the front axle which are handled in the forging machine. After one end of the bar has been formed to the desired shape, the other end of the bar is heated and passed through the same operations. Before the front axles are passed on to the final drop-forging operations, the burrs and fins formed in the forging machine dies are removed.

The final forming of the front axles is done under a steam hammer of the type shown in Fig. 19, the dies illustrated in Fig. 20 being used. Only one end is completed at a time; this will be seen by referring to the dies shown in Fig. 20. The axle is heated for a little over one-half its length and is placed on the lower die in the steam hammer. The operator is careful to locate the end of the bar so that the stock to form the knuckles is in the proper position in relation to the impression in the die before the first blow is struck; then ten successive blows are struck and the axle is removed and taken to a punch press holding a shearing die which removes the fins. The axle is then brought back to the steam hammer, given a final blow and laid down to cool off in the sand.

After one end of a batch of front axles has been finished in this manner, the other end is heated and carried through the operations described. The axles are then again taken to the furnaces, heated and placed in a fixture held in a punch press. where they are stretched to the exact length—52½ inches.

CHAPTER II

WELDING IN THE FORGING MACHINE

There are three methods in general use for welding or joining pieces together in a forging machine. The selection of the one to employ depends largely on the shape of the work and other requirements. The most common method in general use is lap-welding, of which there are several applications. The next method in importance is pin-welding. Butt-welding is as a rule used only where it is impracticable to handle the work in any other way.

In regard to the materials that can be handled, wrought iron can be very readily welded in the forging machine, and when proper care is taken this can be successfully done without resorting to the use of fluxes except in unusual cases. Machine steel does not weld as readily as wrought iron, and usually it is advisable to use a welding compound on the faces of the parts it is intended to join. The following ingredients make a satisfactory flux for steel welds: To one part of sal-ammoniac add twelve parts of crushed borax. Heat slowly in an iron pot until the mixture starts to boil, then remove and reduce to a powder. Then apply the powder to the welding faces of the work shortly before removing it from the furnace, putting the work back in the furnace for a short period after applying the flux. Alloy steels, while they can be worked successfully in a forging machine, cannot be successfully welded. As a rule, parts made from alloy steels can only be worked into shape by upsetting and forming.

Lap-welding and Forming Operations

A simple example of lap-welding in conjunction with a forming operation is shown in Fig. 21, where the various steps in the making of a draw-bar hanger are illustrated at *A*, *B* and *C*. The first operation consists in cutting a 2 1/2 by 3/4-inch bar of wrought iron to a length of 19 3/4 inches—this allowing a sufficient amount of excess material to form the two bosses, one on each end. The bar is then heated in the furnace and placed in the side shear of the machine as shown at *D*. The forging machine is now operated and the tools held on the side shear arrangement partly cut off the bar and bend the nicked end around about one-quarter turn. It is then removed from the machine, placed on an anvil, and the bent end lapped over as shown at *B*, after which it is again put in the furnace and heated to the proper temperature, it is then removed and placed in the lower impressions in the gripping dies, being properly located for length by the back stop *E*. The machine is then operated, completing the weld and forming the upset square boss on one end of the bar in one blow. After performing the operations described on all of the bars, the other end is handled in practically the same manner, using the upper impressions in the gripping dies and subjecting the bar to three heats instead of tw

Dies and Tools for Making Locomotive Ash-Pan Handle

Fig. 6 shows a locomotive ash pan handle that is produced in a similar manner to the draw bar hanger shown in Fig 21, the operations on this piece being indicated at *A*, *B*, *C* and *D*, respectively. The first operation is to cut off a bar *A* of the required length, as before mentioned, and bend one end over into the shape at *B*, putting it into the required condition for welding, forming and piercing in the forging machine The welding and forming operations which are indicated at *C* are handled in the lower impression of the dies shown to the left of the illustration, the position of the work before forming being indicated by the dotted lines *E*. The lower impression is formed as shown in the end view of the dies at *F*, being provided with a draft in the impression of 1/16 inch on the diameter in order to facilitate the "flow" of the metal and the removal of the forging from the dies. The punch *G* is made with a concave end which forms a portion of the

Fig 21. Making Draw bar Hangers in a 3-inch Ajax Forging Machine

boss and upsets the material into the desired shape at the same time.

After being welded and formed, the work is removed from the lower impressions and placed in a vertical position in the upper impressions in the dies Here the square hole, as indicated at *D*, is punched. As the gripping dies are made from steel castings, they would not stand up satisfactorily for a piercing operation, so in order to punch a clean hole two steel plates *H* and *I* are inserted in the movable and stationary members of the dies These are so shaped that a square hole is formed when the dies come together The hole is pierced by the punch *J*, the construction of which is clearly shown in the illustration Both punches *G* and *J* are made from steel forgings and hardened.

Dies and Tools for Making Car Float Stanchion Foot

Another interesting example of lap-welding which is used for the purpose of enlarging a 2-inch bar to 6 inches in diameter to form the head on a car float stanchion foot is illustrated in Fig 22 This car part, as indicated at *A* and *B*, is made from a wrought-iron bar 2 inches

in diameter, to which a rectangular block *A*, 6 by 3½ by ¾ inch, is welded. Block *A* is first cut to the required length, and bent into a U-shape in the bulldozer. Then it is placed on the round bar as indicated at *B*, and the two parts are put in the furnace, where they are heated to a welding temperature. The parts are now quickly removed, given a tap to stick them together, placed in the forging machine, and with one blow are formed to the shape shown at *C*. The dies and tools used for this operation, which are also shown in the illustration, are of simple construction, consisting only of two gripping dies and one plunger.

Dies and Tools for Making Locomotive Spring Bands

A lap-welding operation which is handled in a different manner from those previously described is shown in Fig. 23. This piece, which is a

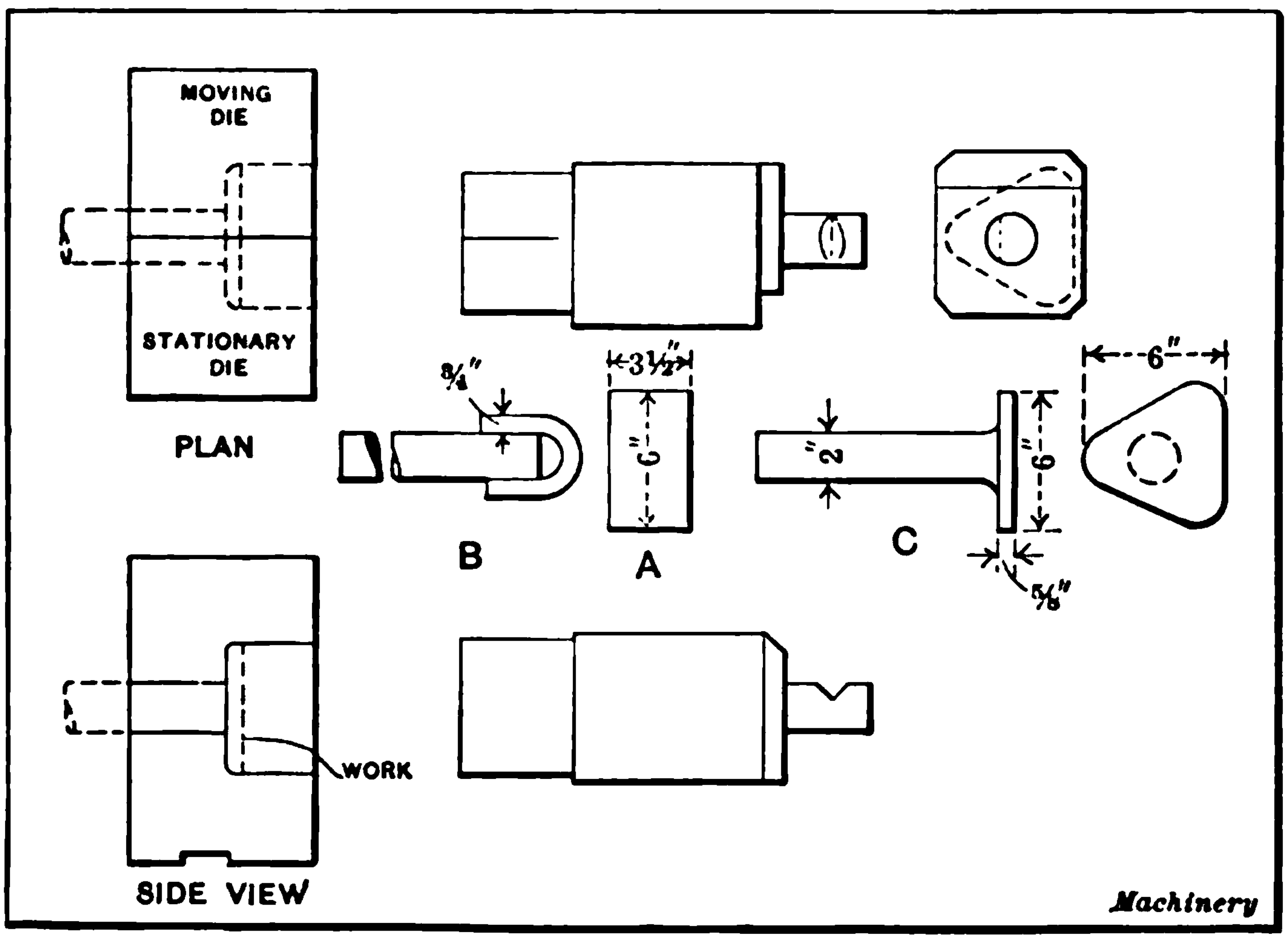

Fig. 22. Forging Machine Dies and Tools for making a Car Float Stanchion Foot

spring band for a steam locomotive, is made from a rectangular wrought-iron bar 2¼ by ⅜ by 19 inches long. It is first bent into a U-shape, as indicated by the full lines at *B*, in a bulldozer. After being bent in the bulldozer, the work is again put in the furnace and heated to the proper temperature. It is then removed from the furnace, and by means of bending dies held in the side shear of the forging machine, the ends are bent into the shape shown by the dotted lines *a*—partly over-lapping each other. After this operation, the piece is again placed in the furnace, heated to a welding temperature, and quickly removed and placed between the gripping dies shown to the left. The stationary gripping die carries two pins *D*, which serve as a means for supporting the work before the dies close on it. The welding and forming operation is accomplished by plunger *E*, which forms the work around the square impressions *F* in the dies, and at the same tim
ends together, forming the spring band into one p

interesting feature about this job is the fact that the excess amount of stock formed by the overlapping ends is distributed equally along the front side of the forging, making it 1/32 inch thicker than the original rectangular bar, and thereby increasing its strength at this point.

Dies and Tools for Making Extension Handle for Grate Shaking Lever

An interesting example of lap-welding is illustrated in Fig. 24, where the dies and tools used for forming an extension handle for a grate shaking lever are illustrated. This part, as shown at *A* and *B*, is made from two pieces—a rectangular bar of wrought-iron 2½ by ¾ inch, which has been sheared to an angular shape on one end—and a loop *B* formed from a piece of ⅝-inch rectangular bar iron bent into a U-shape in the dies illustrated to the left. The trimming of piece *A* and the bending of piece *B* is carried on at the same time with special shaped formers held to the top faces of the gripping dies. To do this,

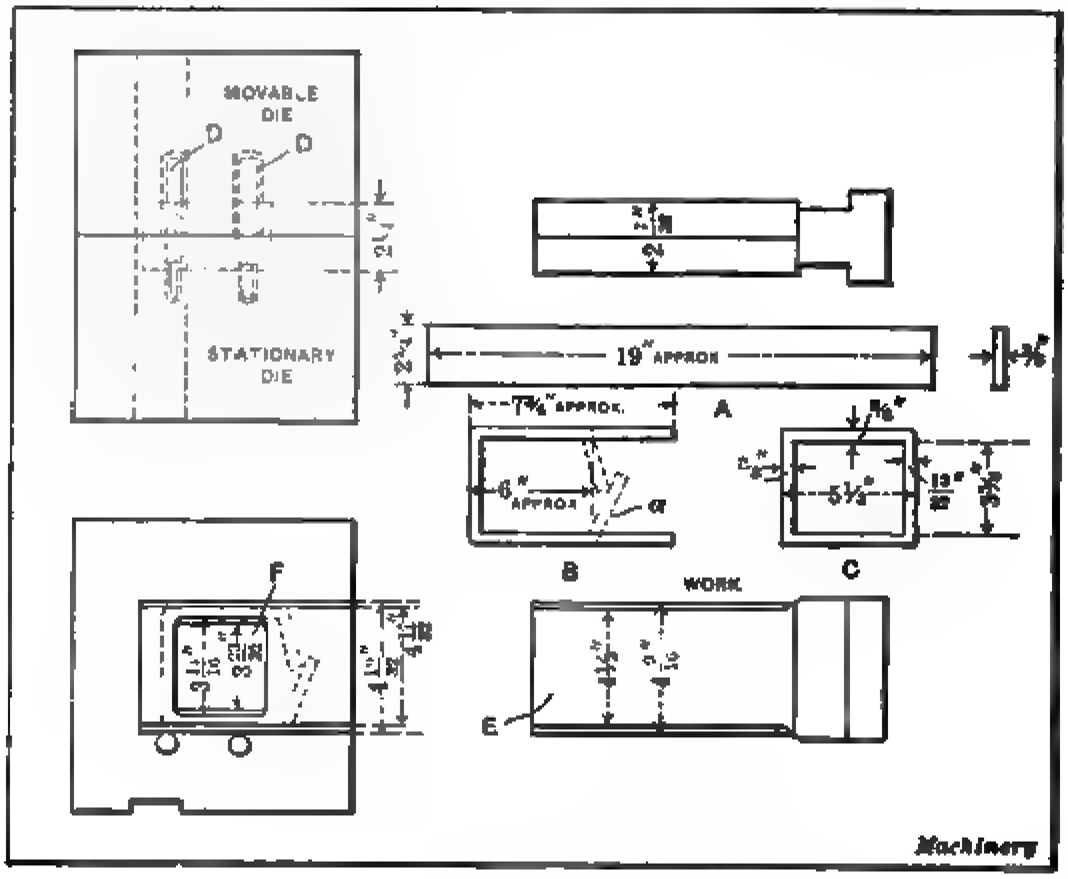

Fig. 23. Forging Machine Dies and Tools for making Locomotive Spring Bands

the operator first places a piece of rectangular stock of the required length in the impressions in the rear member *D* of the stationary gripping die; he then takes bar *A*, which has been previously cut to the required length, and places it in the impression at the front end of the gripping die. Upon operating the machine, the moving die advances and as it carries a plunger *E*, it forces bar *B* into the suitably shaped impression in the stationary gripping die. At the same time that this operation is being accomplished, the shearing plates *F* and *G* carried in the stationary and movable gripping dies, respectively, shear off the end of bar *A*.

The welding of these two parts is accomplished in the lower impres-

sion in the gripping dies which hold the pieces in position while punch *H* advances and upsets and welds the parts together The two pieces are placed together and put in the furnace, heated to a welding temperature, then removed and given a tap, so that they will stick together. They are then put in the

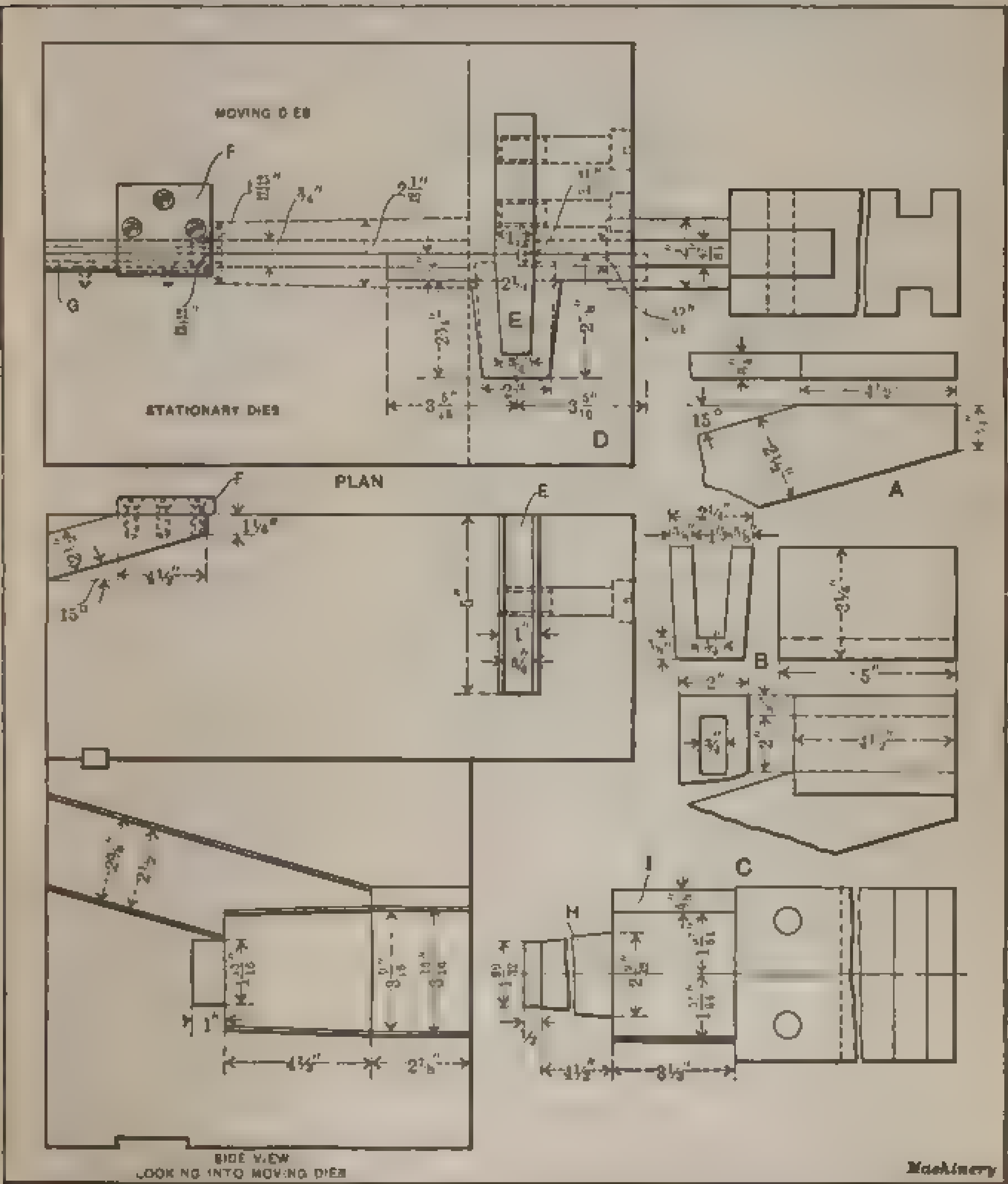

Fig. 24. Forging Machine Dies and Tools for making Extension Handles for Grate Shaking Levers

lower impression of the gripping dies and the machine operated. Then as the plunger *H* advances it enters the loop in part *B*, expanding it into the impressions in the gripping dies, and at the same t he shoulder on the punch, carrying forward the excess qually

throughout the forging, thus joining the two parts and producing a perfectly welded joint. Punch *H* is guided when in operation on the work by a tongue *I*, which slides in a corresponding groove in the gripping dies, and thus prevents any side movement of the punch.

Universal Type of Upsetting and Forging Machine

The miscellaneous welded and formed parts shown in Fig 25 were forged in the Chicago shops of C & N W. Railway. The forging dies and tools shown in the following illustrations constitute a few of the many interesting examples to be found in the shop mentioned All of the examples shown in Fig. 25 were produced on the 6-inch Ajax universal forging machine shown in Fig. 26

The universal type of upsetting and forging machine shown in Fig

Fig 25 Miscellaneous Examples of Lap-welding and Forming Operations accomplished on a 6-inch Ajax Universal Forging Machine

26 has a much greater range of possibilities for producing machine made forgings than the regular upsetting and forging machines previously described. This machine has all the features common to the regular forging machine in combination with those of a powerful vertical press operated independently of the other part of the machine The universal forging machine is designed especially for forming such forgings as require squeezing, punching or trimming operations either before or after upsetting This often makes it possible to prepare and complete large upsets and difficult shaped forgings in one handling, and thus utilize the initial heat.

Fig. 26. Six-inch Ajax Universal Forging Machine used in the C. & N. W. Railway Shops for making the Forged Parts shown in Fig. 25

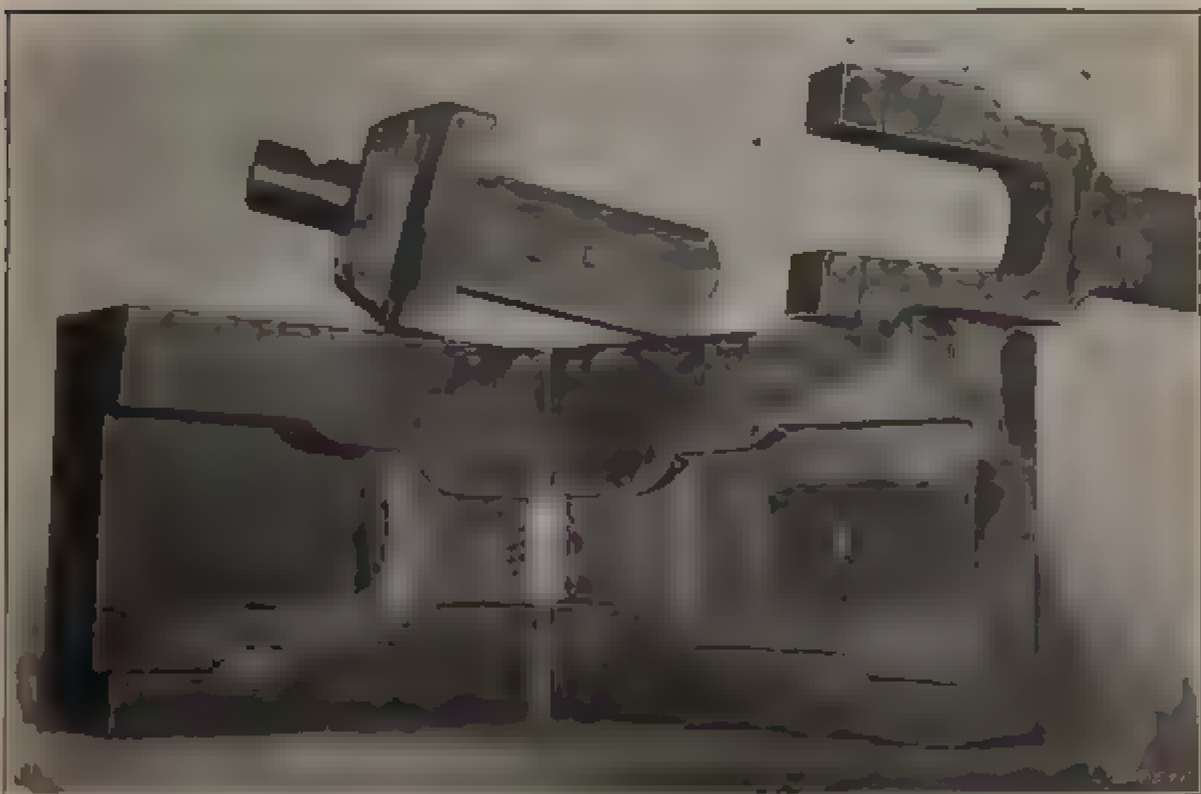

Fig. 27. Dies and Tools used in making Locomotive Main Rods in the 6-inch Ajax Universal Forging Machine

It consists mainly of a double-throw crankshaft from which are operated two header slides—one for the standard upsetting mechanism and the other for the vertical press. The upper die-holder *A* of the vertical press is operated by two heavy steel side links, the lower ends of which connect with eccentrics on an oscillating shaft. This die-holder is provided with means of adjustment so that the squeezing dies can be brought together or separated as requirements demand. The lower member of the dies used in this auxiliary part of the machine is held on the stationary die-holder *B*.

Dies and Tools for Making Spring Hangers

An interesting example of the utilization of scrap metal for making engine parts is the spring hanger *A*, Fig. 25. This part is made from old arch bars 1 by 4 by 5 inches, with the dies and tools shown in Fig. 28. Six blocks cut off from the arch bars are piled together and

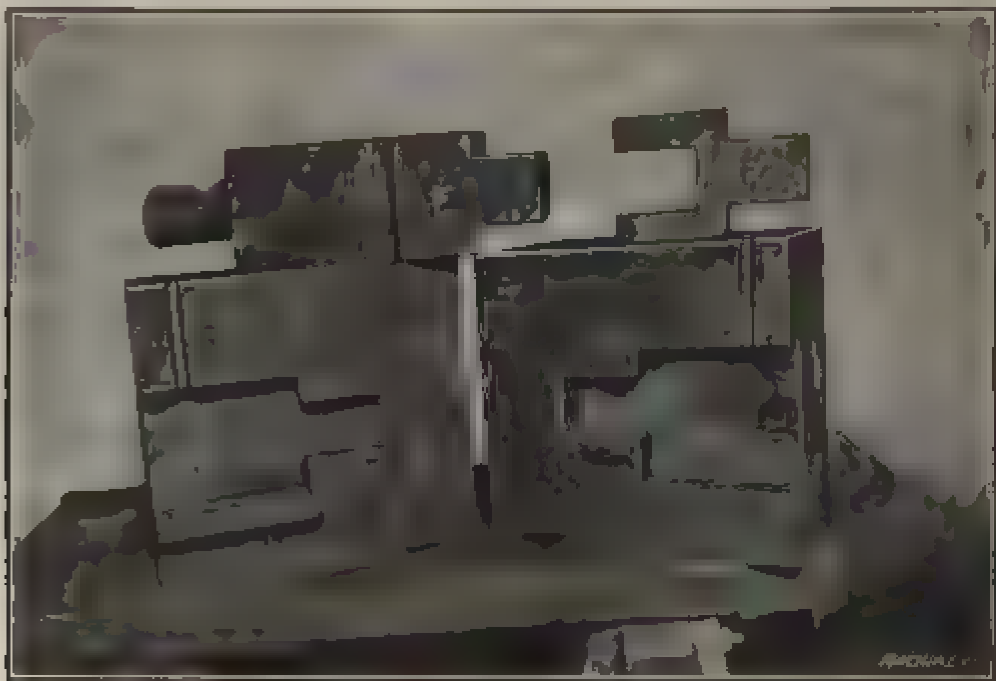

Fig. 28. Dies and Tools for making Spring Hangers in a 6-inch Ajax Universal Forging Machine

riveted as shown at *A* in Fig. 29, the old holes in the arch bars serving as a means for riveting them together. This is done to hold the separate blocks in place while reaching a welding heat. After the parts have reached the proper temperature they are taken to the universal forging machine shown in Fig. 26, and placed between squeezing dies held in the vertical press. The machine is then operated, welding the pieces together and converting them into a solid block as shown at *B* in Fig. 29.

After the separate pieces have been welded and shaped, the solid block is again taken to the furnace and heated to a welding temperature. Then it is removed and placed between the opposing faces of the gripping dies *B* and *C*, Fig. 28, these being held in the forging machine shown in Fig. 26. The stationary gripping die *B* is provided with the shelf *D* on which the heated block is placed, this serving to hold it while the dies are coming together. As soon as the dies close on the

work, plunger *E* advances and displaces the stock in such a manner as to form the tail on the end of the forging *F* by simply forcing the center portion of the block back into the rear impressions in the gripping dies. This is accomplished in one heat, and when the piece is removed from the dies it is finished complete. Vent holes *G* are provided in the opposing faces of the dies to allow the excess metal to escape.

Another example of a spring hanger forging is shown at *B* in Fig. 25, the dies and tools used being shown in Fig. 30. The first operation in the forging of this spring hanger is to draw the 2-inch wrought-iron bar *A* down to the shape shown at *B*, Fig. 31, in a Bradley steam hammer. This piece, after being drawn down, is heated and placed in a

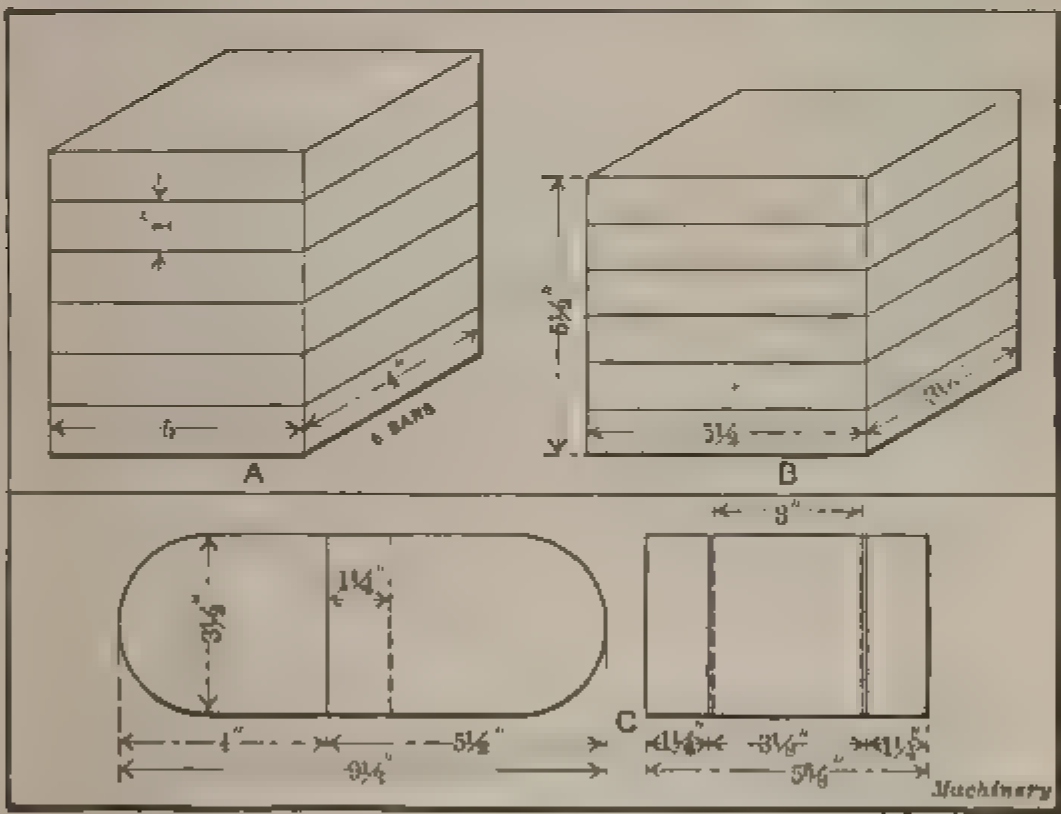

Fig. 29. Sequence of Operations on Spring Hanger shown at A in Fig. 25 and also in Fig. 26

bulldozer, where it is bent into a U-shape as shown at *C*, the heaviest part of the piece being located at the bent end. The one-inch hole is punched through the bent end at the same time that the work is being formed. The body or shank of the hanger is made from a 1 by 4-inch piece of round edge iron *D* which is swaged down on a 4-inch forging machine to 1¾ inch round for a length of about 7 inches on one end, as shown at *E*. The bar is then heated, placed in the forging machine and upset to 2 inches in diameter in order to completely form the reinforced portion on the flat part, and at the same time reduce the end to one inch in diameter The reduction on the end of the bar is accomplished with the plunger held in the ram of the machine.

The loop *C* is now placed on the reduced end of the rod as shown at *G* an riveted cold, just enough to hold the two pieces together

The work is then raised to a good welding

he lower groove *A* (see Fig. 30) of the

dies held in the 6-inch forging machine shown in Fig. 26, where the work is formed by plunger *B* (Fig. 30). The reason for doing this work in a 6-inch forging machine is that the plunger travel necessary is 14 inches, and this would be impossible on a smaller machine than that having a 6-inch capacity. This 14-inch travel, of course, is after the dies have been closed on the work. After the two pieces are welded together as shown at *H* (Fig. 31) a block *a* of 2-inch square iron 3 inches long is placed in the U-end of the forging as shown at *I* and a welding heat taken. The work is then placed in the upper groove *C*, Fig. 30,

Fig. 30. Dies and Tools used in making Spring Hanger shown at B in Fig. 25—also illustrating Pin Welding Operation

of the dies and as the plunger *D* advances it upsets the forging to the proper shape around the embossed center portions *E*, the excess metal flowing up through the vent holes *F* provided in the gripping dies. The finished forging is shown at *J* in Fig. 31

Still another type of spring hanger which is completed in the forging machine is shown at *C* in Fig. 25. This is made from a rectangular bar of wrought iron which is first lapped over and then welded, after which the eye end is formed to shape on the forging machine. The square hole is rough-formed by the vertical press of the universal forging machine shown in Fig. 26, and is then finished in the upper impression in the dies held in the horizontal part of the forging machine. No material is removed to form the square hole, the metal simply being expanded, increasing the width of the bar

Dies and Tools for Making Fork End of Main Driver-Brake Pull Rod

The fork end of the main driver-brake pull rod shown at *D* in Fig 25 is made from a 2¼-inch bar or round wrought iron which is first squeezed down flat on one end until the flattened end is 3 inches wide by 14 inches long. This operation is handled in the vertical head of the machine shown in Fig. 26. A piece of ½ by 3 by 14-inch wrought iron is laid on the flattened portion of the bar (both pieces, of course, being heated) so that they can be stuck together by the dies held in the vertical head of the universal forging machine, thus holding them while the welding heat is being taken. The next step in the forging of this fork is to increase the diameter of the rod from 2½ to 3 inches square. This operation is accomplished in the upper grooves *A* of the dies shown in Fig 32, using the plunger *B* for upsetting. The 3-inch squared end is now split for about 9 inches of its length with suitable

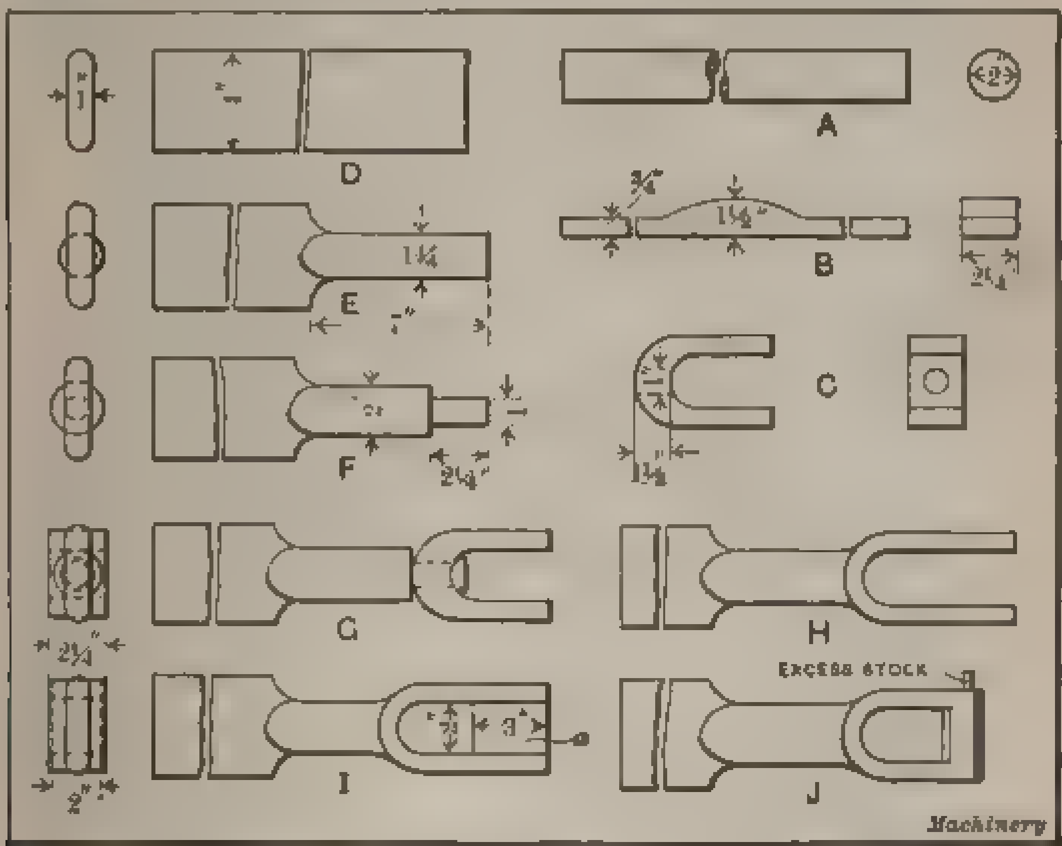

Fig. 31. Sequence of Operations performed on the Spring Hanger B shown in Figs. 25 and 30

tools held in the vertical head of the machine, and at the same time is opened up slightly. The piece is then taken to the furnace and heated, after which it is placed in the lower grooves *C* of the dies, and with one blow of plunger *D* is brought to the final shape shown at *E*.

Dies and Tools for Making Slot End of Main Driver-Brake Pull Rod

The slot end of the main driver-brake pull rod shown at *E* in Fig 25 is made as shown in Fig. 33 from two pieces *a* of 1 by 2½-inch flat bar iron 27 inches long, one piece *b* of 3-inch square iron 3½ inches long, and one piece *c* of 2½-inch square iron 5 inches long. The two pieces *a* are clamped by a pair of tongs on the end where the block *c* is located and a welding heat is taken on the other end. The work is then

removed from the furnace by the tongs and quickly placed in the top groove of the dies. The machine is operated, and as the plunger, which has a punch on its front end, advances, it punches a hole in the work and displaces the stock, forming a boss on each side as indicated at *B*. The position of the tongs on the work is then reversed and the other end of the forging is heated, after which it is swaged to 2½ inches in diameter for a distance of 5 inches on this end to the shape shown at *C*. This operation is handled by the gripping dies which are provided with circular grooves located between the upper and lower impressions. The forging is again heated and placed in the

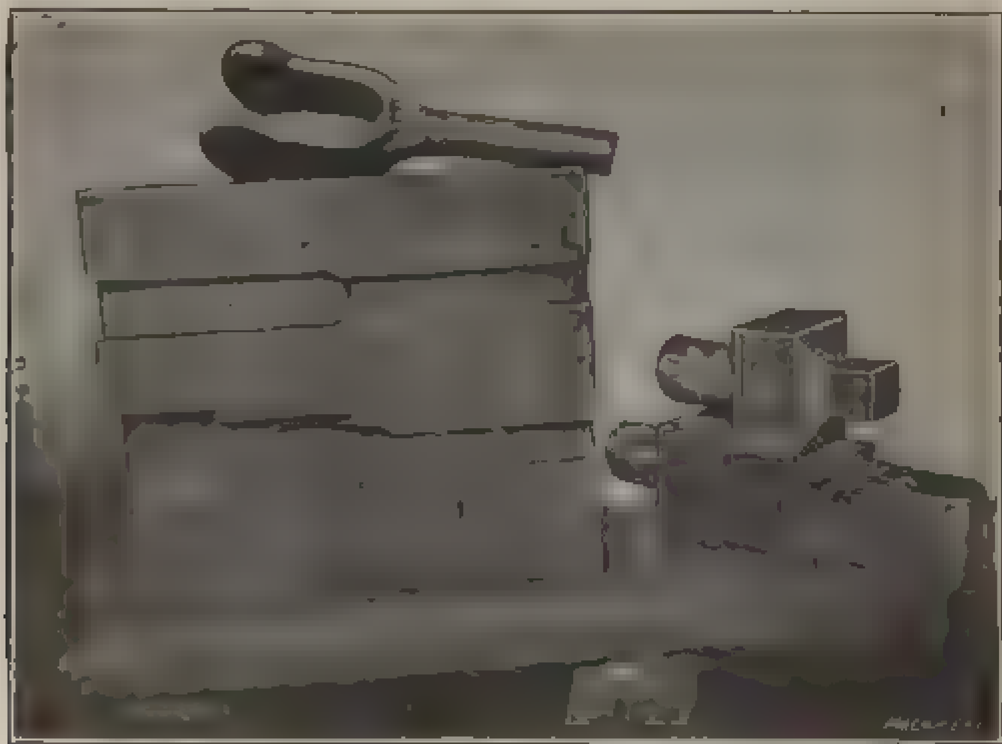

Fig. 32. Dies and Tools for making Fork End of Main Driver-brake Pull Rod shown at D in Fig. 25 in a Forging Machine

lower impressions of the dies, the round part entering the plunger. The machine is then operated, forming the forging to the shape shown at *D*.

Butt-welding Bottom Connecting-Rods for Freight Cars

Butt-welding is seldom done on forging machines, owing to the difficulty generally experienced in successfully making this type of weld. The bottom connecting-rods shown at *F* in Fig. 34, are, however, produced satisfactorily by butt-welding in the Collinwood Shops of the L. S. & M. S. Railway. The stock for the forked ends *A* is sheared off from a bar of 2½ by ¾-inch wrought iron and bent to a U-shape in the bulldozer. The center portion of this connecting rod is made from 1¾-inch round wrought-iron bars which are also sheared to the required length before coming to the forging machine.

The U-shaped pieces *A* and bars *B* are now placed in a furnace where they are heated to a welding temperature. The operator then removes a rod and also a U-shaped piece and butts them together; he then places the pieces which are stuck together in the impressions in the gripping dies *C* and *D*, and operates the machine. Now as plunger *E*, which has a pointed end, advances, it for[illegible] through the fork

into the round stock, thus intermingling the grain of the material and insuring a solid weld. To prevent scale from forming on the pieces to be welded, a small jet of compressed air is made to play on them just before and while the machine is operating.

After welding, the work is removed from the gripping dies and placed between suitably shaped forming dies held in the side shear.

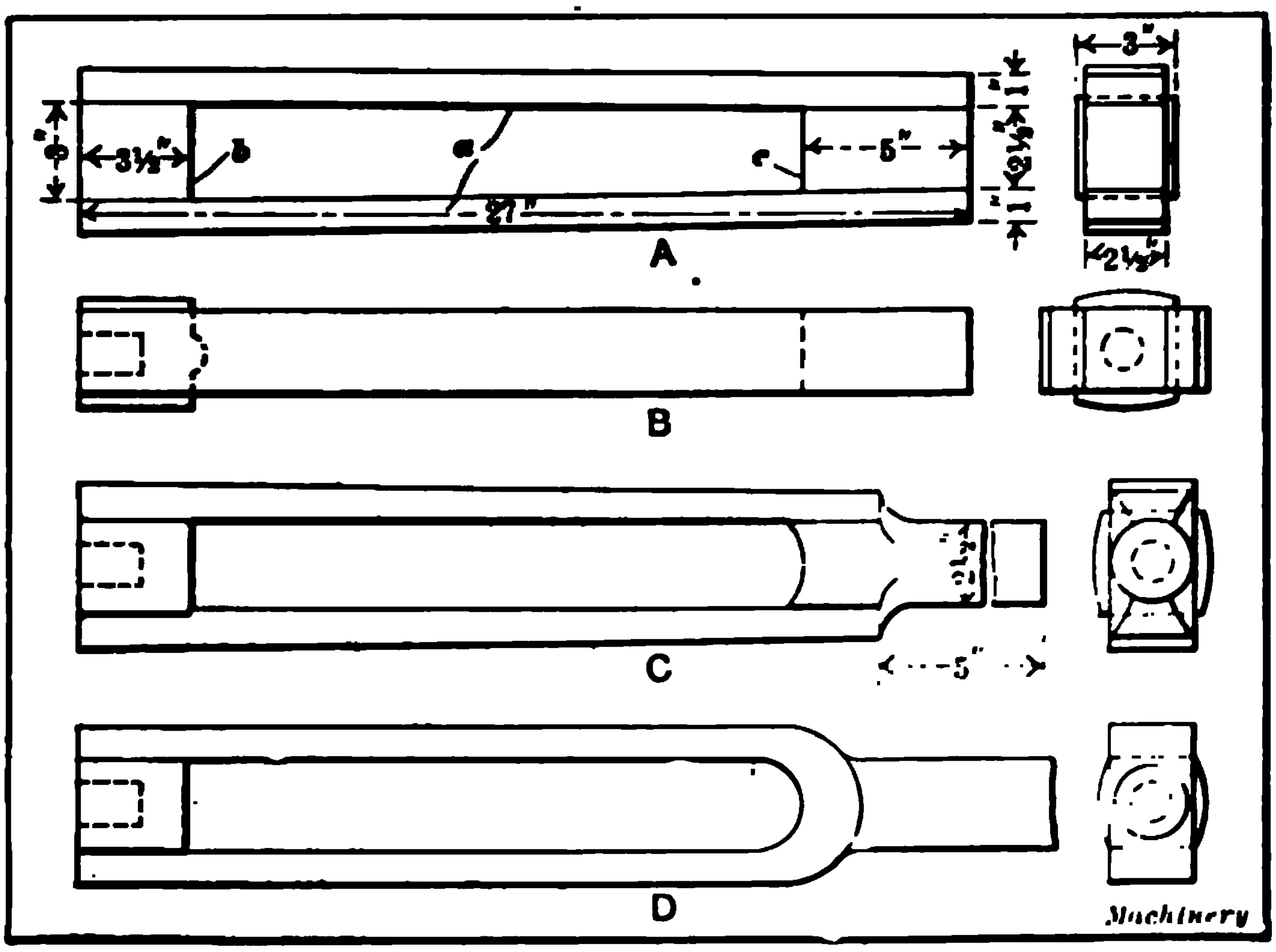

Fig. 33. Sequence of Operations performed on the Slot End of the Main Driver-brake Pull Rod shown at E in Fig. 25

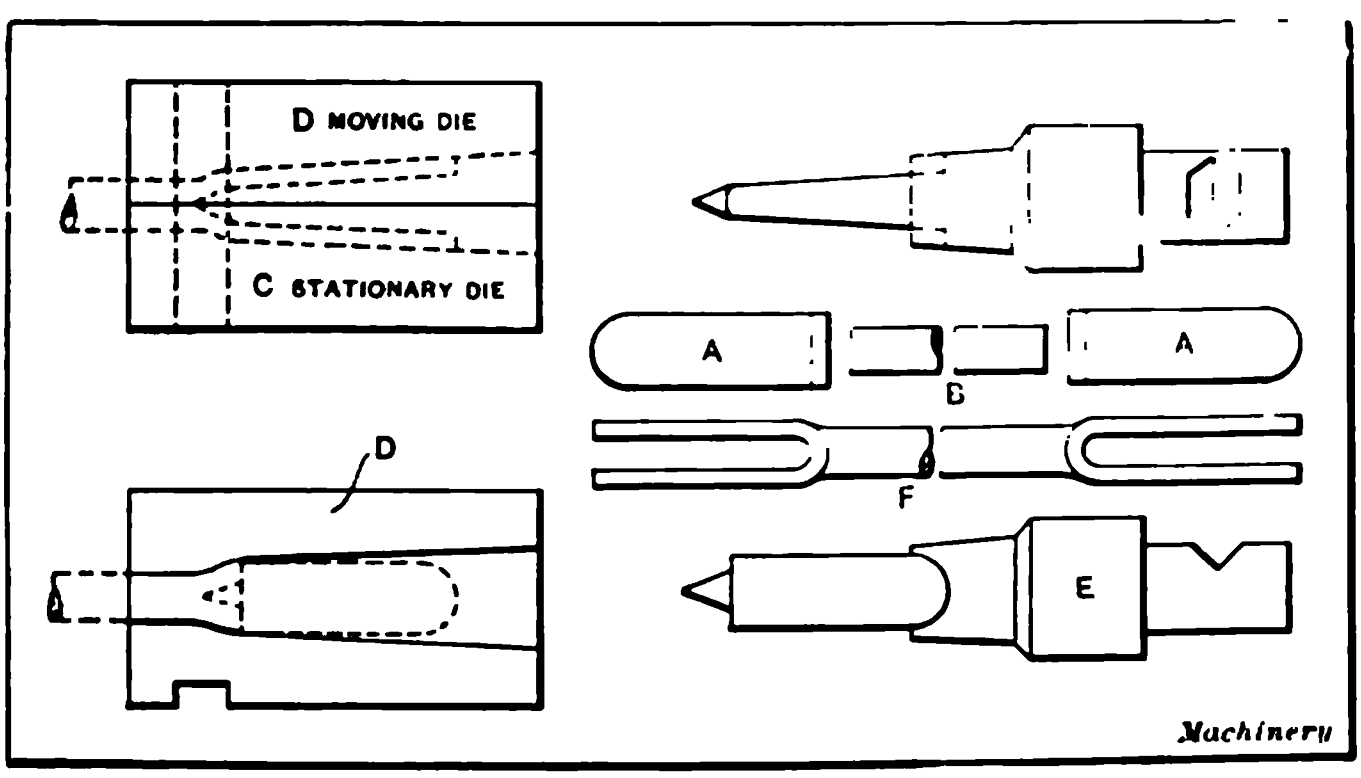

Fig. 34. Illustrations showing Sequence of Operations in the Butt-welding of Bottom Connecting-rods

The machine is then operated, forming the U-shaped end to the proper shape, after which the piece is thrown down in the sand to cool off. After all the rods have been completed in this manner, the other or straight end is placed in the furnace and the same procedure repeated. The con ottom connecting-rods are shown at *F*. To prove that

this type of weld was satisfactory, numerous tests were made to break it at the welded joints. This was not accomplished until the testing machine registered a pull of 74,000 pounds, which is equivalent to a tensile stress of approximately 30,000 pounds per square inch. As the tensile strength of wrought iron seldom exceeds 48,000 pounds per square inch, it will readily be seen that this type of weld would be satisfactory for the general run of forged work.

The Bulldozer as an Auxiliary to the Upsetting and Forging Machine

Considering the fact that so many parts completed on the forging machine can be handled successfully only when partially formed by the bulldozer it may not be out of place to include a short description of this type of machine. Fig. 35 shows the type of bending and punch-

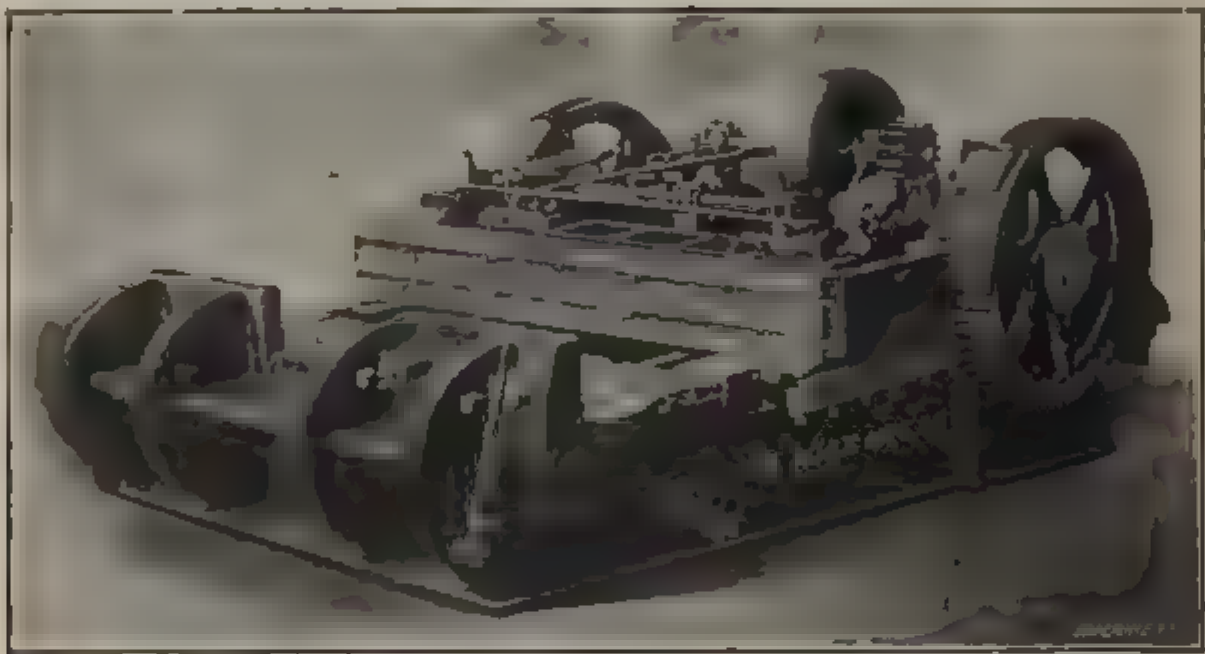

Fig. 35 Ajax No. 7 High-speed Bulldozer—an Adjunct to the Forging Machine

ing machine known as the bulldozer, which is used extensively as an auxiliary to the forging machine in the manufacture of many forgings.

The construction of this type of machine is simple, consisting primarily of a moving crosshead *A* which carries one member of the forming dies, the other member of the forming dies being held against the toes *B* of the machine. The operations are accomplished by the forward travel of the crosshead, the work as a general rule being completed in one travel of the head. Of course, while the machine is fairly simple in construction and operation, many types of interesting forming tools are used.

The forming tools for the bulldozer can generally be made cheaper and more conveniently from cast iron, especially when they are provided with hardened steel plates where any friction takes place; that is, those parts of the tool which actually do the forming or shaping should, as a general rule, be reinforced with hardened steel plates. This enables the tools to be renewed very cheaply, as the plates when worn out can be replaced by new blocks of steel. The roller type of tool which is carried and operated by the crosshead is the best saving material and power when it is possible to use this type. It

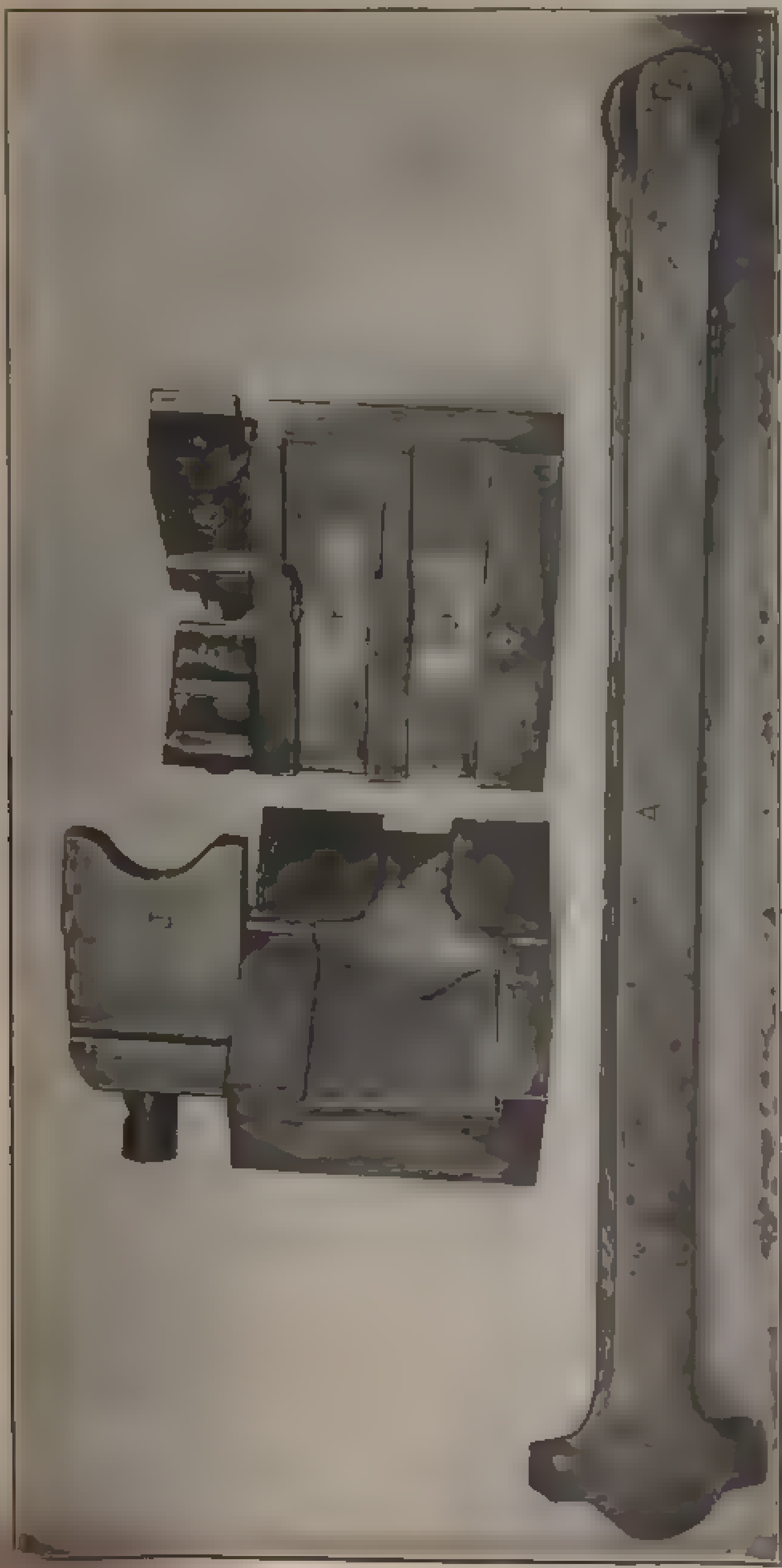

Fig. 38. Dies and Tools used in the Ajax 6 inch Universal Forging Machine for making Locomotive Side Rods in the C & N W Railway Shops

ever, the type of tool to use depends largely on the shape to be formed and other requirements. In all cases where hot punching or cutting is done, high-speed self-hardening steel should be used for the working members of the tool.

Tools for Making Engine Main and Side Rods in the Forging Machine

The locomotive main rod shown at *A* in Fig. 27 is the largest piece of work ever handled in a forging machine in the Chicago shops of the C. & N. W. Railway. The main rod is first roughed out under a steam hammer and the end split before it is brought to the forging machine shown in Fig. 26. The roughing out of the slot and the finish-forming in the forging machine are done in one heat. In the forging machine the work is gripped by the dies *B* and *C*, and is upset and formed to shape by the plunger *D*.

Another good example of heavy forging done in the Ajax 6-inch universal forging machine is the locomotive side rod shown at *A* in Fig. 36. This side rod is made from square stock drawn down to the required size under the steam hammer, and is upset and formed on each end in the forging machine shown in Fig. 26. The gripping dies, only one of which is shown at *B* in Fig. 36, are used for forming the end *C* of the rod. It requires two operations to complete this end. The first operation is performed in the lower groove *D* of the dies and consists in rough-forming the slot with the plunger *E*. The work is then placed in the upper groove *F* and completely formed to shape by means of plunger *G*.

The other end *H* of the side rod is upset and formed to shape by another set of dies—only one of which is shown at *I*. The rod, which is heated to a welding temperature, is placed in the impressions in the gripping dies and is upset and formed to the required shape by means of the plunger *J*. These two examples of machine forging illustrate very well the adaptability of the forging machine to locomotive building.

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ELECTRIC MOTOR DRIVE FOR MACHINE TOOLS

CONTENTS

CHAPTER I

APPLICATION OF MOTORS TO MACHINE TOOLS*

For the shop where electric power is already installed, all kinds of machine tools may be purchased completely equipped with individual motors. When, however, it is desired to institute a change in a shop that has been employing belts and shafting, and to substitute electric power, it becomes necessary to consider each of the belt-driven tools separately, so as to secure as nearly as possible the same results that are obtained with the tools built for motor drive. At the same time excessive expenditures in the alterations must be avoided. It is the purpose of this article to outline the principles of motor application, and to suggest methods by which the belt-driven tools may be accommodated to motor drive.

The first problem to consider is that of the transmission of the power. In large plants, covering acres of ground, alternating current is employed in order to permit the use of high voltages with the corresponding saving in the copper used for wiring. In plants consisting of but a few buildings, grouped fairly close together, the use of direct current possesses advantages in variable speed possibilities that far outweigh the gain to be secured by the use of the high-voltage alternating current. It is, therefore, the general practice at the present time to use 230-volt direct current for the operation of plants of the nature of machine shops, in which a large part of the load will consist of motors driving tools requiring variable speed. Where long transmissions make the distribution of power by alternating current a necessity, a motor-generator may be installed at the point of distribution for the purpose of supplying direct current to the variable-speed motors. This is often the system employed in the case of railway shops which are spread out over a considerable territory and contain a large proportion of constant-speed tools. Here the transmission current is 440 volts, alternating, and the constant-speed motors are operated on this current, while the motor-generator supplies 230-volt direct current for the operation of the variable-speed motors.

Types of Motors

In the first place the three types of direct-current motors should be thoroughly defined, so that the proper type may be selected for the particular tool to which the motor is to be applied. These three types are series-wound, shunt-wound, and compound-wound motors.

The series-wound motor is one in which the field winding is in series with, or forms a direct continuation of, the armature circuit, so that all of the current that passes through the armature passes

* Mainly from an article by George H. Hall in MACHINERY, June, 1912.

also through the fields. The amount of current drawn from the line by a motor depends upon the work, or horsepower, which the motor is developing. It therefore follows that in the series motor the strength of the fields will depend upon the load which is placed on the motor, and as the speed of the motor depends inversely upon the field strength, the speed of the series motor will be inversely proportional to the load. Since the speed of a motor also depends upon the voltage that is impressed upon the armature, the speed of a series motor may be controlled by introducing resistance in series with the armature, and this is accomplished by means of a controller which is used also for starting the motor. The use of the controller enables the operator to start the motor slowly under light loads, and also prevents too great a flow of current when starting under heavy loads. The characteristics of the series motor are heavy starting torque and a speed dependent upon the load.

The shunt-wound motor is one in which the field winding is connected across the main lines, or is said to be in shunt with the armature circuit. The amount of current passing through the fields is inversely proportional to their resistance, and, except in the case of the variable-speed motor which will be treated later, remains practically constant under all conditions of load. This results in a constant-speed motor whose output, in horsepower, is dependent upon the current, in amperes, which passes through the armature. The characteristic of the shunt-wound motor is approximately constant speed under all conditions of load.

The compound-wound motor is one having both a shunt and a series field winding. The shunt field is connected to the main line as in a shunt motor, while the series field is in series with the armature and carries all of the current passing through it as in the series motor. The field of an average compound motor is composed of about eighty per cent of shunt winding and twenty per cent of series winding, although this proportion may be varied to suit the class of work for which the motor is to be used. The speed of a compound motor is more nearly constant than that of a series motor, but the drop in speed from no load to full load is considerably more than in a shunt motor, owing to the action of the series part of the winding. The characteristics of the compound motor partake of those of both the series and the shunt motors in about the same degree as the relative proportion of the two windings composing the field.

Selection of Direct-current Motors for Factory Use*

The prospective purchaser should ascertain accurately the desired speed or speeds of the machine to be driven, and the maximum horsepower as well as the average horsepower required to do the work. The speed or speeds of the driven machine may be ascertained by tests conducted with an experimental motor, or from data furnished by the builder of the machine, where such information is available. Often

* Abstract of an article by Earle D. Jackson in the "Engineering Magazine," September, 1911.

the motor drive is to replace a steam drive, or individual motor drives are to replace an existing motor-driven group drive, in which cases the speeds are easily determined

Horsepower Required

The horsepower required to do the work should be determined as accurately as possible The purchaser may rent an experimental motor and ascertain the power required, which is probably the most satisfactory way to solve the problem. The group drive generally requires that this testing be done, as the amount of power required under actual conditions for a group of machines of different kinds and sizes is problematical, and the information cannot be obtained from the machine manufacturers as can often be done in the case of an individually driven machine It should be remembered in this connection that from the input to the test motor as measured with a wattmeter, or with a voltmeter and ammeter, should be subtracted the test-motor losses, as the motor to be purchased is rated on horsepower output or brake-horsepower Money spent in the accurate determination of the amount of power required is wisely expended—a fact often overlooked by the factory manager

Machine-tool builders, motor manufacturers, and central stations are often called upon to supply the information as to how large a motor should be. Without accurate data, the machine-tool builder often overestimates the horsepower required for driving his tools, in order to be on the safe side, with the result that the motors run at one-quarter to one-half load day in and day out, at greatly reduced efficiency. The electrical losses, together with interest and depreciation on the unnecessary extra investment, may amount to a considerable sum in a large installation It certainly behooves the machine-tool builder to have on hand (and, of course, many of them do) accurate data acquired from carefully conducted tests, covering the performance of his motor-driven machines under all conditions of load and speed.

The motor manufacturer often has in his own establishment individual machine-tool drives and group drives similar to those of the prospective purchaser, in which event he can supply the necessary information as to the size of the motor Many up-to-date central stations also have a vast amount of data on power required for different motor drives, derived from actual tests under working conditions, which are always available to a prospective power consumer

The piece-worker requires a relatively larger motor for the same tool than does the operator working by the day In the former case, heavy cuts at the higher speeds will be the rule, together with quicker starting and more continuous running of the motor, as the piece-worker crowds his machine to the limit, and must be provided with ample motor capacity. Nothing is more discouraging to a workman than to find out that the motor will not perform all the work he requires of it, or is continually giving trouble

Group Drives*

A few years ago when the electric motor drive began to take a prominent place in manufacturing plants, many factories changed from the old method of belting the engine to a large drive shaft, which was connected by belts to long lines of shafting throughout the plant, to the individual motor drive having a separate motor attached to each machine. The owners soon discovered that this made a very expensive installation, and this form of drive, although the most flexible, is gradually giving way to the group drive for light machine shop work. In the group drive a motor drives a short length of lineshafting which, in turn, drives the machine tools. This arrangement makes the first cost considerably less than that of the individual motor drive, and if planned systematically it is almost as flexible as the latter method.

The best arrangement for the group drive is to divide the machine shop into small units, having a motor for each department or each kind of machines. The lineshafting should be as short as possible and the motors placed in accessible positions, so that they can be watched and easily replaced in case of a breakdown. A small platform makes an excellent mounting for a motor, as it can be easily inspected and removed if found necessary. Experience has proved that motors suspended from the ceiling do not receive as careful attention, and a further disadvantage of this method of mounting lies in the fact that the motors are difficult to replace when set up in this way. With the proper equipment, a motor can be removed from a platform and a new motor installed in less than fifteen minutes. By carefully planning a group drive system, all the lineshafting can be run at the same speed and a standard size motor adopted for the entire shop. This does away with the necessity of carrying a number of different sized motors in stock and standardizes the motor equipment of a factory.

It is often impossible to obtain reliable data for figuring the proper size of motors to drive machine tools. During the installation of mechanical equipment in an automobile engine factory, the machine shop was carefully laid out and a copy of the drawing, together with the sizes of machine tools, kind of work, speed and other technical information were sent to the different machine tool builders with the request that they give the exact power requirements for their machines when operating on the group drive system. The replies were carefully tabulated and after a careful analysis, it was shown that machine tool builders were giving the same results for group drive as for the individual drive, overlooking the fact that some of the machines would be idle and others consuming only a small amount of power at the time when the remaining machines were absorbing the maximum amount of power. These conditions all tend to equalize one another, so that the average power used by each machine would be considerably less for the group drive than the maximum power demanded for the individual drive.

* From an article by Harry C. Spillman in MACHINERY, June, 1913.

POWER REQUIREMENTS OF MACHINE TOOLS

Kind of Machine	Kind of Work	Per Cent of Machines Running	Floor Area for Machine and Operator in Square Feet	Total Average Power Per Machine in Watts*	Total Average Power Per Machine in Watts†	Friction and Line-shaft Load Per Machine in Watts†	Average Power Used in Doing Actual Work in Watts*	Total Power Per Square Foot of Floor Area in Watts
No. 2 Horizontal Rockford Boring Mills	Boring Bearings in Aluminum Cases	85	150	1620	1320	1100	800	8.8
No. 4 Cincinnati Millers	Light Milling of Aluminum	100	120	995	995	880	500	8.3
16 inch Lodge & Shipley Lathes	Turning Small Forgings	60	55	900	555	500	87	10.1
Double Disk Grinders, Double Buffers, Two Wheel Emery Stands	Grinding and Polishing	55	55	1800	1000	300	880	18.2
24 inch Bullard Vertical Lathes	Heavy Cuts on Cast Iron Flywheels	100	100	1350	1350	850	1000	13.5
24 inch Gould & Eberhardt Gear Cutters	Cutting Small Cast Iron Gears	100	65	333	338	250	88	5.5
Four Head Ingersoll Milling Machines	Making Four Cuts on Cast Iron Cylinders	100	800	3550	3550	2300	1250	11.9
Baker Single and Bausch Multi Spindle Drills	Drilling and Tapping Cast Iron	40	70	1580	687	550	217	9.1
Heald Grinders No. 60 Internal Grinders ‡	Cylinder Grinding	85	70	2880	2480	1860	500	34.7
No. 6 Whitney Hand Millers	Keyseating Small Cast Iron Gears	60	40	365	220	120	165	5.5
Landis No. 2 Grinders	Grinding Cam Shafts	80	90	1875	1500	1000	625	16.7
Norton 10 by 30 inch Grinders	Grinding Pistons and Small Forgings	70	100	2000	1400	1100	450	14.0
Jones & Lamson Flat Turret Lathes	Machining Small Forgings	85	65	975	560	200	375	8.6
Eight Spindle Cincinnati Gang Drills	Drilling and Reaming Connecting Rods (8 holes)	100	110	2840	2840	2000	840	25.8
Potter & Johnston Automatics	Turning Small Cast Iron Gears	100	75	690	690	440	250	9.2
1½ inch Gridley Automatics	Machining Cast Iron Pistons	100	200	1520	1520	1250	270	7.6
No. 4 Warner & Swasey Turret Lathe	Machining Small Forgings	65	55	500	360	310	70	6.5
24 inch Cincinnati Drill Presses	Small Drilling on Forgings	90	40	520	474	345	100	11.8

Machinery

* Deducting Idle Machines. † Including Idle Machines. ‡ Exhaust Fan not considered.

Careful tests which have been made since the machine shop was placed in operation show that the shop takes less than one-fifth of the power recommended by the machine tool builders, or in other words, they were figuring over five times too high for the group drive.

The accompanying table gives the results of the tests. It also shows that the lineshafting and countershafting consume thirty per cent of the total power, and the total friction losses absorb seventy-two per cent of the total power. This makes a forty-two per cent loss of power from the countershafting to the machine tools, and only twenty per cent of the total power is utilized in doing work. The electrical loss shows eight per cent of the total power. In the table there are two items mentioned as follows: Total average power per machine, deducting idle machines; total average power per machine, including idle machines. These items include all the mechanical power of that department, such as lineshafting, countershafting, machine friction and power consumed in doing work on the machines. In the first case this total power is equally divided among all the machines which are in operation. In the second case it is divided equally among all the machines, both running and idle. The electrical losses are omitted in all cases.

Having determined the speeds of the driven machines and the horsepower required to do the work under all conditions, a knowledge of the various types of direct-current motors is the next essential in order that a motor may be selected which will fulfill the conditions required of it in the most acceptable manner.

Selection of Motors

To determine the type of motor to be employed for the different classes of tools in the machine shop, the character of the power requirements of the tools should be carefully analyzed. In the case of lathes, boring mills, milling machines, etc., in which the work of cutting is continuous, it will be seen that the tool is required to run at a speed which can be adjusted to the character of the work being machined, and when so adjusted will remain practically constant. Also, the tool is usually started before the work of actual cutting begins, so that no excess of power is needed to start. The foregoing requirements correspond to the characteristics of the shunt motor, and for this class of work this motor should invariably be used.

In the case of planers, shapers, slotters, etc., the work is intermittent, being far greater at some portions of the stroke than at others, and for this class of work the compound motor is best suited. The same type of motor is also used for the operation of punches, shears and other tools having heavy flywheels, as the motor will slow down at the period of greatest load, which is just after the completion of the stroke. The actual cut is effected through the inertia of the flywheel, and the maximum load on the motor is that of accelerating the flywheel and bringing it back to normal speed after it has carried the tool through the work.

When operating hoists and cranes, the motor must be started under the full weight of the load to be handled and at the same time slowly enough to prevent the shock of too sudden acceleration. These requirements are best met by the series motor with a controller having a heavy starting resistance, as it provides high torque at low speeds. This type of motor is also used for auxiliary purposes, such as raising the cross-rails of planers and boring mills, traversing the carriages of large lathes, and elevating the tables of horizontal boring mills.

Types of Motors for Different Requirements

The general classification of direct-current motors now included in the standard product of nearly all motor manufacturers is as follows:

Approximately constant speed, no load to full load...............	Shunt motor. Shunt-commutating pole motor.
Semi-constant speed, no load to full load......................	Compound motor.
Adjustable speed, remaining approximately constant for one adjustment, no load to full load	Shunt motor, with adjustable field resistance. Shunt-commutating pole motor with adjustable field resistance.
Adjustable speed, semi-constant for one adjustment, no load to full load.............	Compound motor, with adjustable shunt field resistance.
Varying speed, varying with the load	Series motor. Series-commutating pole motor.

Constant speed shunt motors are, of course, used for the operation of groups of machines that are driven by a common countershaft, but for individual drive the constant-speed motor is little used, as one of the greatest advantages of individual drive is the ability to vary the speed of the tool to suit the requirements of each piece being machined. This naturally brings up the question as to where the line should be drawn between tools that should be arranged for group drive and those which may advantageously be equipped with individual motors. No fixed rules can be laid down in answer to this question, but, in general, it is customary to group the smaller tools, as the initial expense of separate equipments for such tools as bench drills, tool grinders, emery wheels, and sensitive drills, often equals or exceeds the cost of the tools themselves. In the tool-room, also, the value of individual equipment is questionable, as the work on each tool is intermittent and there is not the demand for the high efficiency from the tools that obtains in the case of tools used in the manufacturing departments. If the product of a given tool is especially valuable, or forms a very important part of the shop's output, the first cost of the drive is of minor consideration, and an individual equipment which will secure the greatest output is warranted.

Variable-speed Motors

Variable-speed motors, in the generally accepted use of the term, are, strictly speaking, adjustable-speed motors, in that the speed may be adjusted by means of a controller. There are two methods in common practice by which this adjustment of speed may be accomplished. These are known, respectively, as armature regulation and field control.

The first method consists of introducing resistance in series with the armature circuit, thereby reducing the voltage that is impressed on the armature. With constant field strength, as in a shunt motor, the speed of the motor will be directly in proportion to the impressed voltage. If the load on a motor remains constant, the speed will be inversely proportional to the resistance inserted in the circuit, as the torque is in proportion to the current in amperes, and the voltage equals the amperes divided by the resistance. From the foregoing it will be seen that if the motor load varies, the voltage and, therefore, the motor speed will, with a fixed resistance, vary with the load.

Now, consider the output of the motor when armature control is employed; the torque, or turning effort, is proportional to the amperes drawn by the motor, while the horsepower is a function of the product of the volts and the amperes. Thus a motor developing a given horsepower draws from the line a definite amount of current and produces a torque corresponding to that horsepower. If, now, we cut the speed in half, by halving the impressed voltage, while the torque remains the same, the product of the volts by the amperes will be but one-half, and the motor will be delivering but one-half its former horsepower, although it will be drawing just as much current as when delivering the full horsepower. Thus it will be seen that this method of control is uneconomical and gives a speed varying with the load, while the demand of most machine tools is for a drive that will give a desired speed regardless of the load. In employing the method described it is almost impossible to secure slow motor speeds with very light loads. For this reason this method of control is but little used in connection with machine tools.

The second method, that of field control, is most generally used for motors employed in the operation of machine tools. With the voltage impressed on the armature constant, the speed of a motor will be inversely proportional to the strength of the fields. This field strength is directly proportional to the ampere-turns in the field, and as the actual turns of wire must remain constant, the ampere-turns may be easily regulated by inserting resistance in series with the field winding and thus decreasing the current in amperes passing through the field. The torque of the motor is, in this case, proportional to the field strength, and, as the field strength varies inversely as the speed increases, the horsepower of the motor will remain practically constant.

Considering the average class of tools, such as lathes, boring mills, etc., we can readily see that the foregoing motor characteristics

correspond to the requirements. When the cutting tool is run at a high speed, the cut taken by the tool is light, and when taking heavy cuts, the speed is slow, thus calling for a practically constant horse-power throughout the working range of the tool

As the field current is but a small proportion of the total current used by the motor, the total current consumption of motors using this type of control is practically in proportion to the work being done, so that this is an economical method. The speed, also, being regulated by the field strength, is independent of the load, so that for a given controller position it will be practically constant regardless of the power developed. As a matter of fact, the shunt motor with constant field strength will vary about 5 per cent from no load speed to full load speed.

Open or Enclosed Motors

The question whether to employ the open or enclosed motor often arises. The metal covers of closed motors reduce the efficiency and capacity of the motor by preventing free circulation of air around the active elements of the motor Working conditions will usually decide whether it is possible to use the open motor, which is, of course, the desirable practice, or whether the presence of excessive dust makes it necessary to enclose the moving parts of the motor partially or completely The partially or semi-enclosed motor should not be placed in a concealed position for the reason that it is then certain to be neglected in an ordinary factory The perforated covers and wire screens will close up by dust and dirt, and as the result the semi-enclosed motor becomes virtually a totally enclosed motor with a semi-enclosed rating and consequent trouble.

General Considerations

Vertical motors are made in a number of sizes, but are only to be recommended when the nature of the drive makes it apparent that they possess great advantages over the standard or horizontal type, as vertical motors are troublesome to keep in running order and require greater attention. They are not generally kept in stock by local dealers, and the motor, as well as repair parts, must be replaced from the factory stock at the risk of the usual delay in shipment.

Manufacturers' standard sizes and speeds of motors should be chosen wherever possible, in preference to motors of special sizes and speeds, as prices, time of delivery, and general performance of the former will be found to be more favorable than those of special design. In many cases, it will be found impossible to select from the standard sizes and speeds of a single motor manufacturer only, all the motors which are required, and in this case there is no valid reason why the order should not be divided up and the motors purchased from the builders whose standard product meets the required conditions.

The direct-current voltage now practically standardized for factory use is 220 volts. This voltage is both economically and operatively superior for direct-current motor systems to that of 110 volts sometimes employed.

Types of Drives

Having determined the horsepower and selected the type or types of direct-current motors desired, the best means to employ in driving the machines is the next problem that is confronted. In considering a belt drive, a greater pulley reduction than 5 to 1 is not to be recommended. Idlers to increase the arc of contact, or countershafts between the motor and the driven machine to reduce the initial speed of the driver, are doubtful expedients, unless the amount of power used is very small. It is an easy matter to design a belt drive of this kind in which 20 to 30 per cent of the power of the motor is wasted between the motor and the driven machine.

Direct-connected drives, gear drives, and silent chains constitute a list of positive drives from which it should be possible to select a satisfactory method of driving a machine from a motor, in which safety, reliability, and economy of operation are all present. The direct-connected drive is the ideal drive, as it eliminates all intermediate power-absorbing apparatus. In a great many cases, however, the use of the direct-connected drive necessitates the employment of a special motor. It is unfortunate, in this respect, that machine-tool builders and motor manufacturers often disregard each other when it comes to the selection of standard speeds for their respective machines, although they are collaborating more than they did formerly. The silent chain as a means of driving machines is coming into wider use. The early types of silent chains were expensive, rapidly depreciated, and in many installations were far from being "silent." In point of efficiency, the silent-chain drive stands next to the direct-connected drive. The main objection to the gear drive is its excessive noise, but this may be overcome to a large degree by the use of a rawhide pinion.

Specifications

Specifications should be drawn which state in detail the number of motors required, the horsepower of each motor, the desired motor speed or speeds, together with the speed or speeds of the corresponding driven machine, and the name or description of the machine, giving the number of hours of its probable use per day; whether the motor is to be of the open, semi-enclosed, or enclosed type; the line voltage; details of the motor drive, including pulleys, gears, chains and sprockets, of both driver and driven machine; and whether the motor foundations are to be included in the contract price. Specifications should be submitted to at least three reputable motor manufacturers for quotations, giving cost complete in the case of each separate motor, weights and mechanical sizes of motors offered, efficiencies at one-quarter, one-half, three-quarters, and full loads, for all ranges of speed called for, speed regulation from no load to full load, commutation at all loads and speeds, temperature rise, overload capacity, times of delivery, and description of all starting and field or other rheostats to be furnished, as well as complete description of each motor. Each one of the foregoing items should be known,

if intelligent comparison and selection are to be made. The specifications may also call for a test of each motor purchased, to be made by the purchaser or his engineer after the motors are in place and before final acceptance, to demonstrate whether or not all of the required conditions have been fulfilled.

TABLE I. TYPICAL LINE OF VARIABLE-SPEED SHUNT MOTOR RATINGS

Frame	2 to 1 Range			3 to 1 Range			4 to 1 Range		
	H. P.	Min. R.P.M.	Max. R.P.M.	H. P.	Min. R.P.M.	Max. R.P.M.	H. P	Min. R.P.M.	Max. R.P.M.
No. 1	1/2 3/4	625 800	1250 1600	1/4 1/2	475 800	1425 2400	1/4	500	2000
No. 2	3/4 1 1/2	525 800	1050 1600	1/2 1 1/2	525 800	1575 2400	[illegible]	415	[illegible]
No. 3	2 2 1/2	675 900	1350 1800	1 1/2 2	500 675	1500 2025	3/4 1	450 550	1800 2200
No. 4	2 3 1/2	400 625	800 1250	2 3 1/2	400 625	1200 1875	2	400	1600
No. 5	2 1/2 3 1/2	500 725	1000 1450	2 1/2 3 1/2	500 725	1500 2175	1 1/2 1 3/4	450 550	1800 2200
No. 6	2 1/2 4	400 550	800 1100	2 1/2 4	400 550	1200 1650	2 1/2 3	400 550	1600 2200
No. 7	4 5 1/2	400 525	800 1050	4 5 1/2	400 525	1200 1575	5 1/2	525	2100
No. 8	5 1/2 7 1/2	650 800	1300 1600	3 1/2 5 1/2	450 650	1350 1950	3 1/2	400	1600
No. 9	5 7 1/2	325 460	650 920	5 7 1/2	325 460	975 1380	6	450	1800
No. 10	10 12	875 1000	1750 2000	7 1/2	625	1875	3 5	300 450	1200 1800
No. 11	15	750	1500	12 1/2	600	1800	5 7 1/2	300 350	1200 1400
No. 12	20	800	1600	15	575	1725	10 12 1/2	375 450	1500 1800
No. 13	25	750	1500	20	600	1800	12 1/2 15	375 425	1500 1700
No. 14	35	825	1650	20 25	500 600	1500 1800	15	375	[illegible]
No. 15	40	675	1350	25 30	400 525	1200 1575	20	350	1400

The investment in a set of inexpensive but reliable electrical measuring instruments is to be highly recommended in connection with a motor drive For a small installation, the set should include a portable voltmeter, ammeter, and wattmeter. For a large installation, a considerable investment is sometimes warranted Thus on important machines, graphic wattmeters can be installed, showing at

any time of the day the amount of power used. These instruments, moreover, can be moved from place to place, until every motor in the shop has been included, thus acquiring valuable data for shop records. This is especially valuable immediately after a drive is installed as a means of ascertaining whether or not a motor of proper size and characteristics has been selected.

Application of Motors to Machine Tools

Considering the application of motors to specific tools, we can best divide the problems presented into two classes. The first class comprises those tools in which the removal of metal is continuous, such as lathes and drilling machines. The second class contains those tools in which the removal of metal is intermittent, as with planers, shapers and slotters.

For use with machine tools of the first class, variable-speed shunt motors will be employed, and the next point to be considered is the

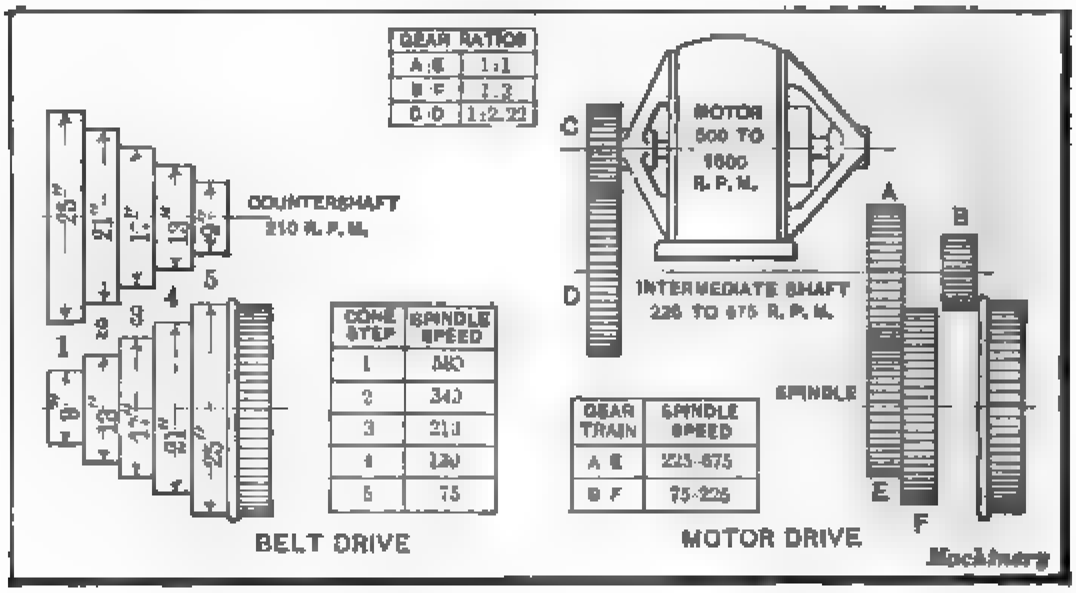


Fig. 1. Comparison of Belt and Motor Drive of Engine Lathe

speed range for which they must be adapted. For a given horsepower the size of the motor will be inversely proportional to the minimum speed, and as the use of gearing or chain drives places a practical limit on the maximum speed, the minimum speed, and consequently the size of the motor, will depend upon the speed range. The best idea of the actual results that can be obtained with field controlled motors may be secured from a table showing the outputs and speed ranges of a standard line of such motors. Although different makes vary somewhat in their ratings from those given in Table I, this gives a correct average of the various lines upon the market.

With a wide motor speed range, a larger part of the working range of the tool is, of course, covered than with a more limited range, but as it is impracticable to cover the entire working range of such a tool as a lathe or boring mill by a corresponding motor range, it is customary to use one or more mechanical speed changes to augment the electrical range. The problem is, therefore, to select a motor speed range that will give satisfactory results without in-

volving too elaborate mechanical changes. Actual experience has shown that, under average conditions, a motor speed range of $2\frac{1}{2}$ to 1, or 3 to 1, together with two mechanical speed changes, will cover practically any range of speed that is obtainable with a cone-pulley drive on any of the ordinary types of machine tools.

To show just how this works out, we will take an actual case of an engine lathe provided with a five-step cone pulley. In making applications to old lathes it is desirable to retain the back-gearing, while the cone is removed from the spindle sleeve and two gears mounted thereon as shown in Fig. 1. The motor is placed above the headstock, on a bracket, and is geared to an intermediate shaft running directly below. This shaft carries two gears, *A* and *B*, either of which may be meshed with its corresponding spindle gear *E* or *F*. The engraving shows a comparison of the spindle speeds obtained with the original belt-drive and those that may be secured by the

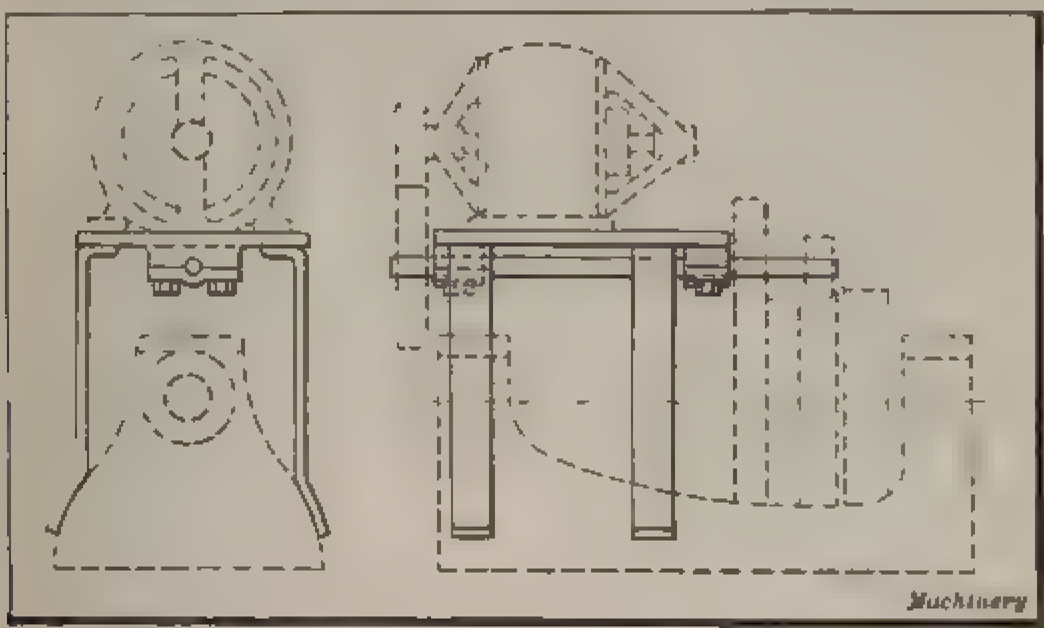


Fig. 8. Plate and Brackets for Supporting Motor

application of a 3 to 1 motor. Not only is the range of spindle speeds increased, but whereas in the belt range of 75 to 580 revolutions we obtained but five distinct speeds, with the motor and a twenty-step controller we obtain a range of 75 to 675 revolutions with forty different running speeds, varying by about 6 per cent. This calculation considers only the range of speeds obtained without the back-gearing of the lathe and the range is, of course, repeated at correspondingly lower speeds by the introduction of the single or double back-gearing with which the lathe is provided.

Just here it may be well to point out one of the greatest advantages of the motor drive. It will be noticed that the belt drive, which gave a range of 75 to 580 revolutions, did so in five steps varying by at least 60 per cent per step. If the lathe is running on, let us say, the fourth step it may be found that the cutting speed, owing to the size of the work or the condition of the tool, is not as high as could be used to best advantage. To jump to the next speed, however, increases the cutting speed over 60 per cent, which will be too much.

and the work will consequently be done on the fourth step, although this may be 30 or 40 per cent below that at which the best economy would obtain. With a motor drive giving speed increments of 6 per cent or less, the work can at all times be done at practically the best speed, and the increase of output that will be thus secured will be readily appreciated.

Another typical case where the advantage of the motor drive is clearly shown is in the facing of a large surface such as a flange. The ordinary practice is to adjust the speed properly for the cut at the largest diameter and then cover the entire surface at this speed, although, as the tool approaches the center, and the cutting diameter becomes smaller, the cutting speed will be too low. To be sure, an

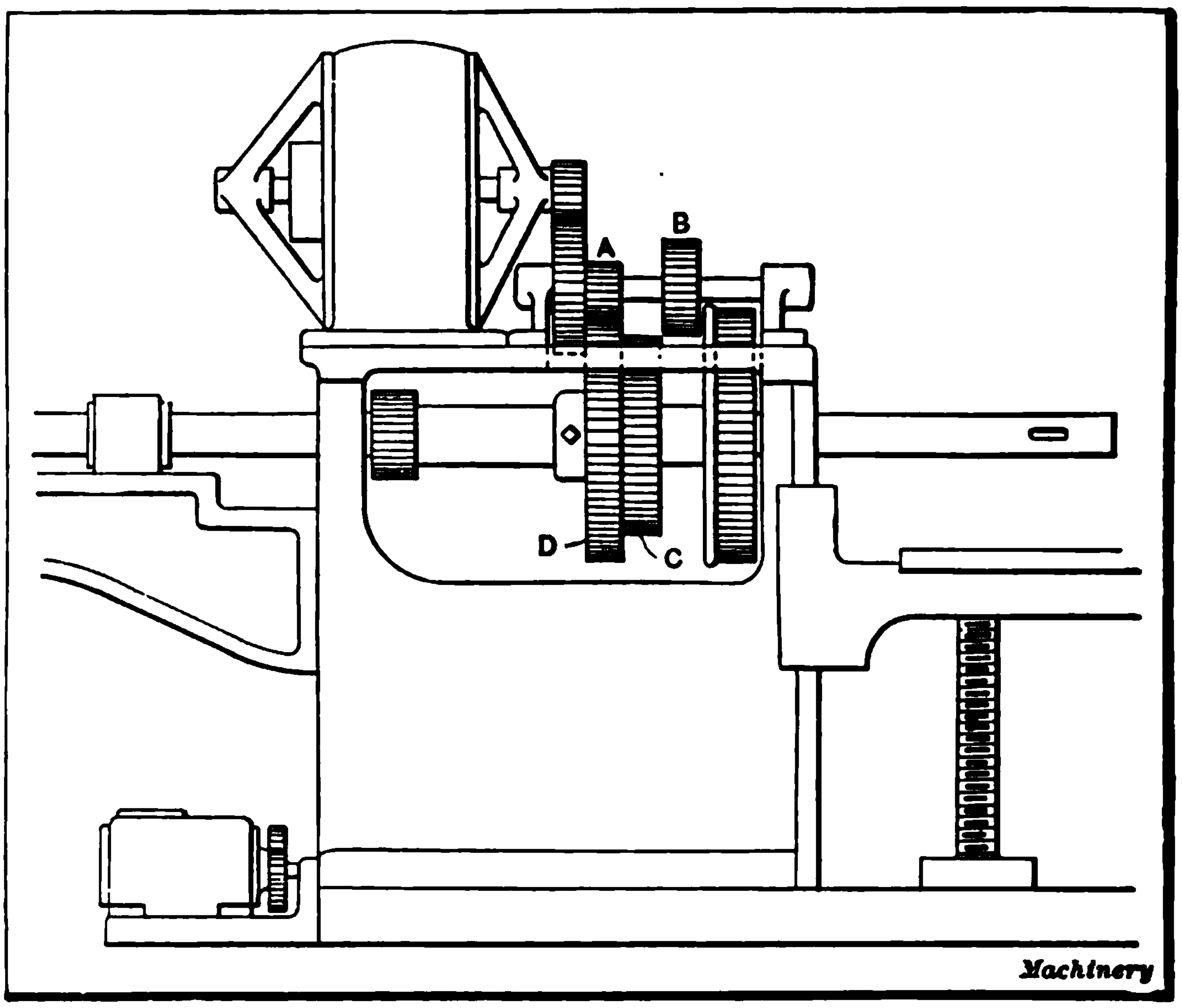


Fig. 3. Motor Equipment of Horizontal Boring Machine

energetic lathe hand can shift his belt from time to time as the work progresses, but this is practicable only after a reduction in speed of the 60 per cent made necessary by the large intervals between the cone steps. With the motor drive, requiring only the slight movement of the controller handle to adjust the speed, the operator will continually "notch-up" his controller, so that the entire surface will be covered at practically maximum speed.

In making this application to belt-driven lathes, if a considerable number are alike, it will be found economical to make a pattern and cast a bracket that can be attached neatly to the headstock. This bracket will be provided with bearings for carrying the intermediate shaft below the motor. As this entails expensive pattern work, it will be cheaper, if the number of similar lathes is small,

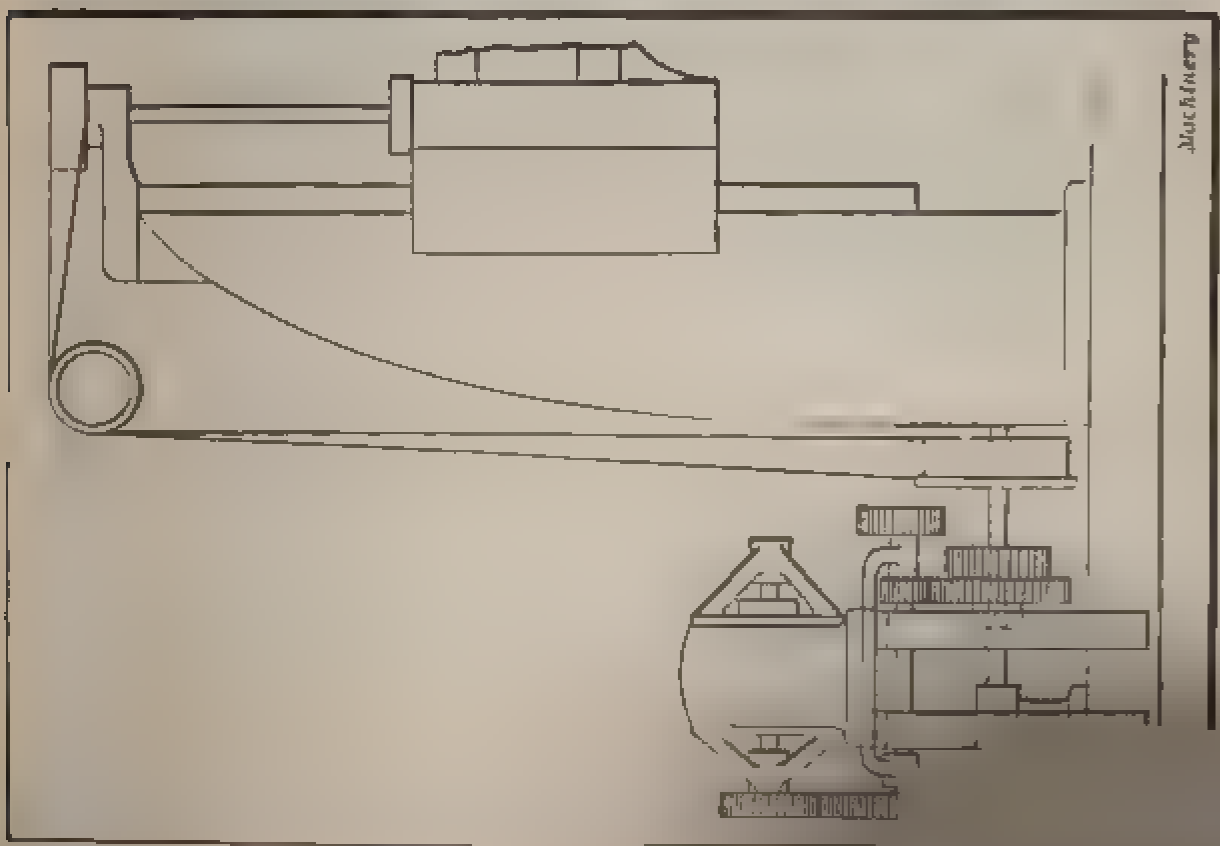


Fig. 4. Motor applied to a Radial Drill

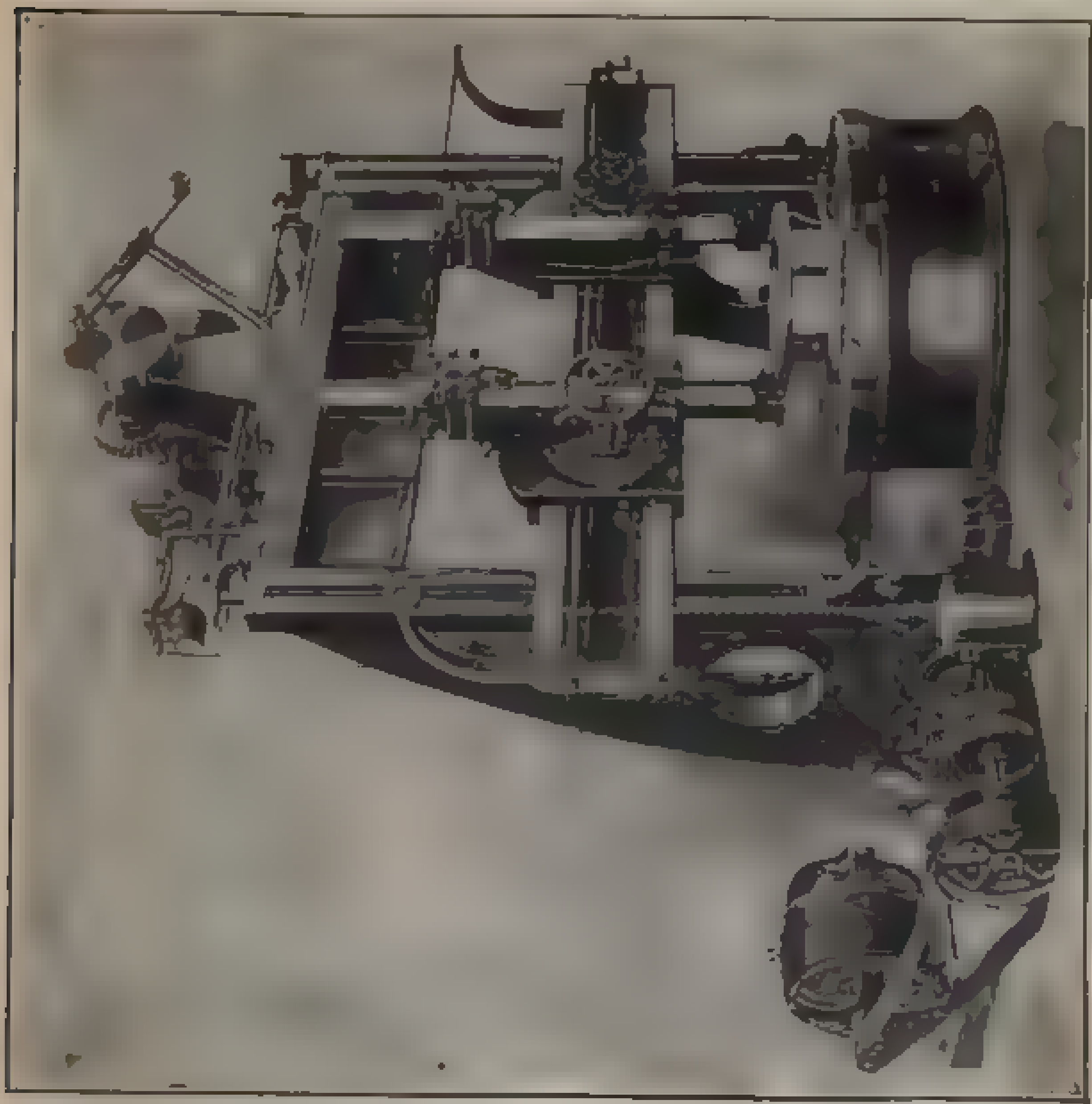


Fig. 5. Motor Equipment of Large Boring Mill

to use wrought-iron brackets to support a plate on which the motor can be placed. This plate will require a very simple pattern which can be readily changed to suit different sizes of motors for various tools with which it can be employed. Fig 2 gives a general idea of such a bracket, and indicates the method of supporting it over the headstock of a lathe.

The same scheme works out very satisfactorily for applying motors to other types of tools, although certain modifications may be needed in order to obtain the best results. Fig. 3 shows a horizontal boring machine which has been equipped in a manner similar to that of the lathe. The cone is replaced by the two gears *C* and *D*, but in

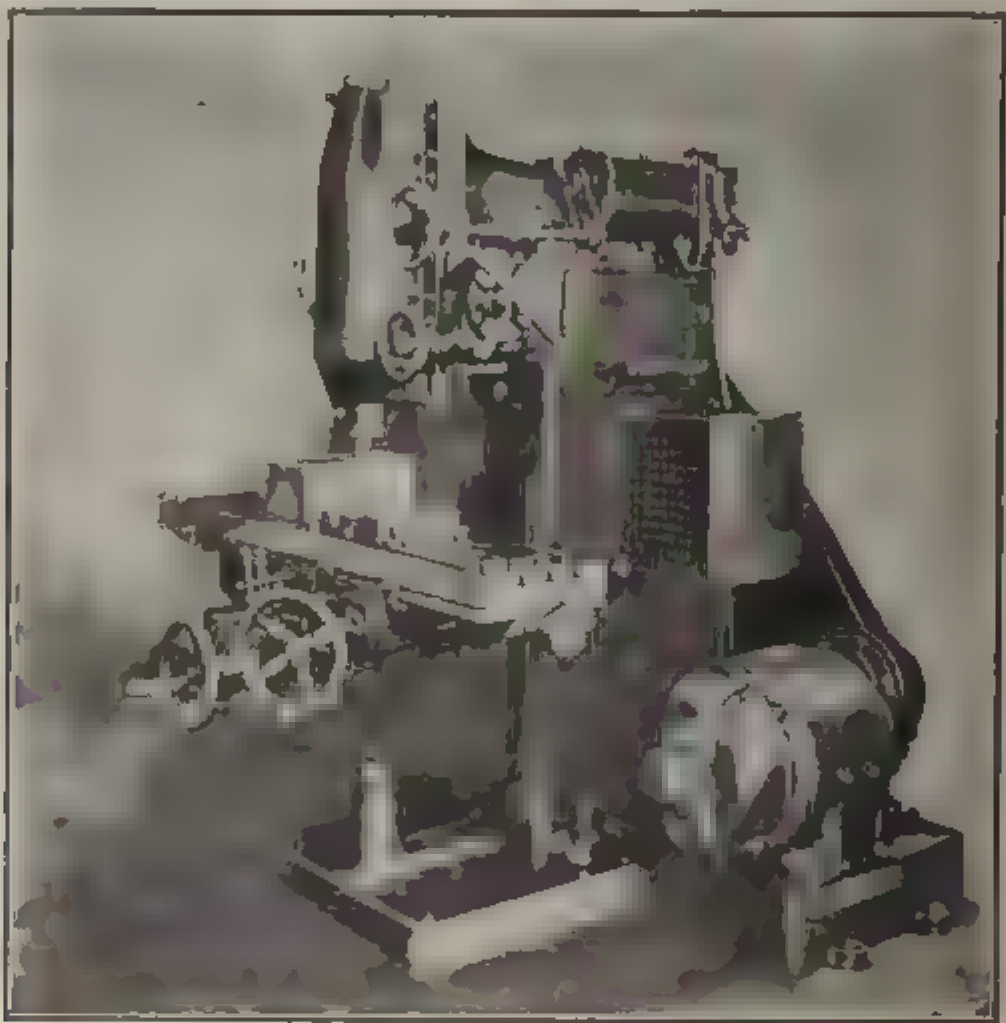


Fig. 6. Motor applied to a Vertical Milling Machine

this case the pinions *A* and *B* are fast on the intermediate shaft, while the gears *C* and *D* are free to slide on a feather in the spindle quill, so as to be engaged at will with their corresponding pinions. The intermediate shaft, in this case, is carried in brackets in front of the motor rather than beneath it. Fig. 4 shows how this type of drive, with underneath intermediate shaft, may be applied to a radial drill, and the same arrangement will be found readily applicable to upright drills.

The halftone Fig. 5 shows the application of a motor drive to a large boring mill. The arrangement is extremely simple, consisting of replacing the driving pulley with a chain sprocket, and driving

from the motor which is set at any convenient near-by point. The two pinions for the gear changes are seen in front of the original driving gears of the mill.

For operating milling machines the most successful applications are made with chain drives. The motor may be placed on a floor base attached to the base of the machine, or it may be bracketed onto the top of the machine, illustrations of both of these arrangements being shown in Figs 6 and 7 The latter motor position is preferable, as the chips from the machine necessitate the use of a fully enclosed

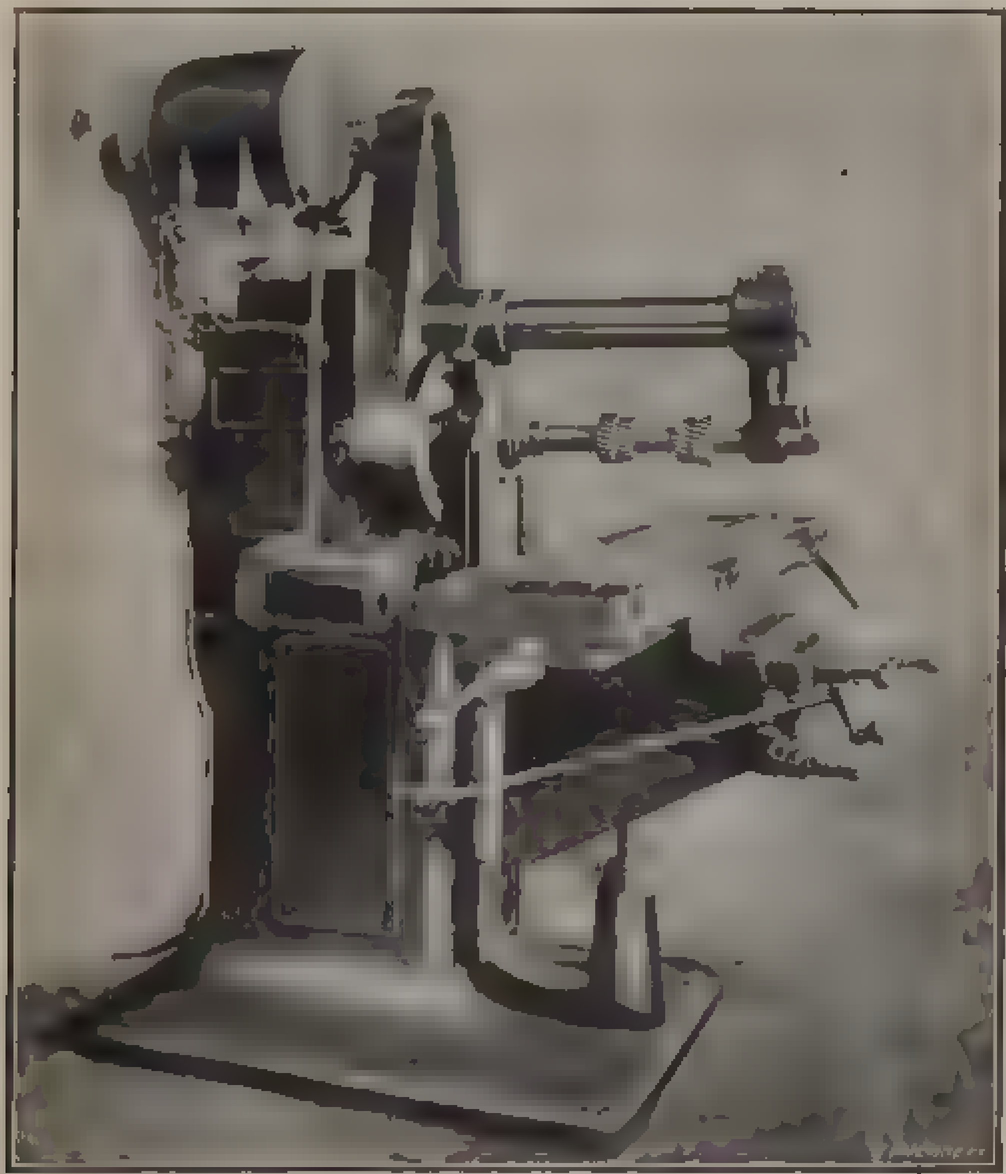


Fig. 7. Motor Equipment of Universal Milling Machine

motor if it is placed below the table of the machine. The examples shown are offered mainly as suggestions, as the construction and speeds of each particular tool will call for separate consideration

Horsepower Required

Having decided upon the desirable speed range and the mechanical details of the application, the next problem is the selection of a motor of suitable power Upon this point no positive rules can be followed, as so many factors enter into the consideration. For the

operation of a lathe for general work a 5-horsepower motor might be fully adequate, while for driving the same size of lathe for manufacturing purposes, and using only high-speed steel at maximum cutting speeds, a 10- or even a 15-horsepower motor might be needed. For running a milling machine, for example, it is obvious that a much smaller motor could be employed if the machine were to be used only for finishing work, with light cuts, than would be needed on the same machine if it were to be used for heavy roughing work. Any tabulated data, therefore, based on the size of the tool, must necessarily give averages only, and should be modified by one's best judgment, based on the actual conditions obtaining.

TABLE II. AVERAGE POWER REQUIREMENTS OF ENGINE LATHES

	Character of Work			Character of Work	
Swing, Inches	Light, H. P.	Heavy, H. P.	Swing, Inches	Light, H. P.	Heavy, H. P.
12	½	1	30	3	5
16	1½	2	36	5	7½
18	2	2½	42	7½	10
20	2½	3	50	7½	15
24	3	5	60	10	20

TABLE III. AVERAGE POWER REQUIREMENTS OF BORING MILLS

Swing, Inches	Horsepower	Swing, Inches	Horsepower
20	1 to 2	72	10 to 12½
30	3 to 4	84	12½ to 15
40	5 to 6	96	15 to 20
50	5 to 7½	120	20 to 25
60	7½ to 10		

A most excellent plan is to determine the power requirements, by actual test, before purchasing the motors. This can be done, at a comparatively small expense, by belting a test motor to each tool successively, and taking readings with a recording ammeter for a day or two while the tool is running under actual operating conditions. Remember that all good motors have a 25 per cent overload capacity for periods of at least two hours, so that if the day's run on a certain tool shows about 7½ horsepower as the average load, with occasional peaks, for short runs, of 8 or 9 horsepower, a 7½ horsepower motor will be sufficient. The accompanying tables which have been compiled from the recommendations of the tool builders and from actual tests, will, with the modifications mentioned, serve as fairly accurate guides in the selection of proper motors.

As universal milling machines are usually rated by numbers, rather than by any dimension, a tabulation of their requirements is somewhat difficult, but for comparison the figures are given for the Brown & Sharpe machines, and these will serve as a guide for the equipment of machines of other makes.

For horizontal milling machines the power requirements may be based upon the machine capacity as expressed by the width between the housings.

Application of Motors to Planers, Shapers, etc.

The second class of tools comprises those in which the cutting stroke alternates with a non-cutting return stroke, as in the case of planers, shapers and slotters. Here the successive operations of the tool occur in cycles, as shown in Fig. 8. The highest points in the cycle are those which occur when reversing takes place As the return stroke is taken at two or three times the speed of the cutting stroke, the power required to accelerate the bed of the planer or the head of the slotter to its return speed usually constitutes the greatest power demand, while a somewhat lower point is reached on the reverse to cut. It is not, however, necessary to power the tool to

TABLE IV. AVERAGE POWER REQUIREMENTS OF DRILLING MACHINES

Swing Inches	Upright, H. P.	Radial, H. P.	Swing, Inches	Upright, H.P.	Radial, H. P.
18	1 to 1½	......	48	2 to 3	3 to 4
24	1 to 1½	......	54	......	3 to 5
36	1½ to 2	2 to 3	60	....	4 to 6
42	2 to 2½	2 to 3	72	....	5 to 6

TABLE V. AVERAGE POWER REQUIREMENTS OF BROWN & SHARPE UNIVERSAL MILLING MACHINES

Machine No.	Horsepower	Machine No.	Horsepower
1	1½ to 2	3	7½ to 10
1½	2 to 3	4	10 to 15
2	5 to 7½		

TABLE VI. AVERAGE POWER REQUIREMENTS OF HORIZONTAL MILLING MACHINES

Width between Housings, Inches	Horsepower	Width between Housings, Inches	Horsepower
12	3 to 3½	36	9 to 10
18	4 to 5	42	12½ to 15
24	7 to 7½	54	15 to 20
30	8 to 9		

meet the extreme peak, as the overload capacity of the motor will take care of this demand. Instead, the average cutting load represents the desirable nominal rating of the motor

In this class of work, a constant speed of the motor is not of as great importance as with constant cutting tools, but it is, rather, desirable that the motor shall be designed to take care of the overloads that occur at the reversals, and for this reason motors for use with tools of this class should be compound-wound. The result is that, as greater demand is made on the motor, the increase of current that passes through the fields strengthens them, and thereby increases the torque of the motor. This also causes the motor to slow down, so that the speed for which the motor should be adjusted is that desired when operating under cutting load. On the return, when the load is light, the motor will consequently run faster than during the cutting stroke

The average cutting speed of any of this class of tools will be between 25 and 50 feet per minute, so that a 2 to 1 range motor is suf-

ficient for nearly all cases and often a range of 1½ to 1 will be found satisfactory. Compound-wound motors are not used for such wide speed ranges as the shunt-wound motors, since any considerable weakening of the shunt field so changes the relation of the shunt to the series winding as to cause the motor to attain the nature of a series motor, which is undesirable.

In some new planers on the market, pneumatic or magnetic clutches are used for reversing, but in equipping old tools it will be found

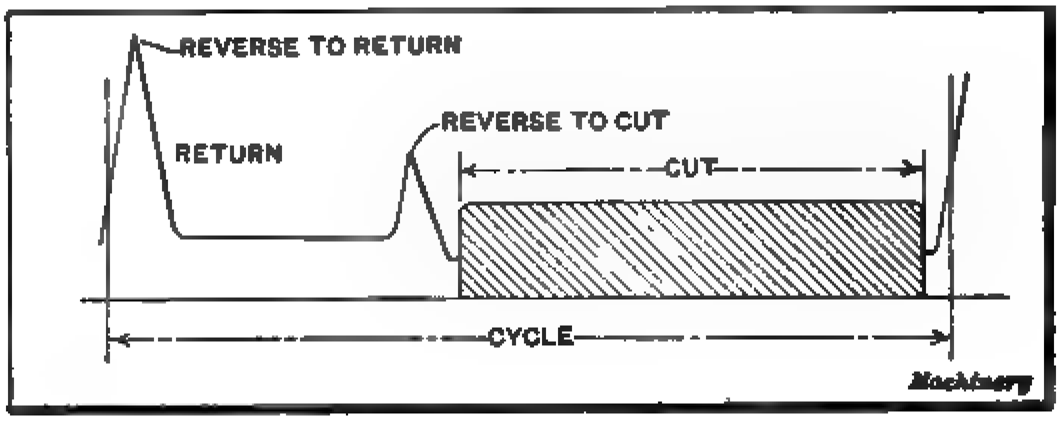


Fig. 8. Cycle of Operations of Planer

more practicable to retain the cross-belt drive with belt shipper. A diagram of such an application is shown in Fig. 9. The motor is mounted on the top of the planer housings, and geared to a countershaft which carries the driving pulleys. The use of the flywheel on the motor shaft is most desirable, as it greatly relieves the motor on the peak loads. By mounting it on the motor shaft, instead of on

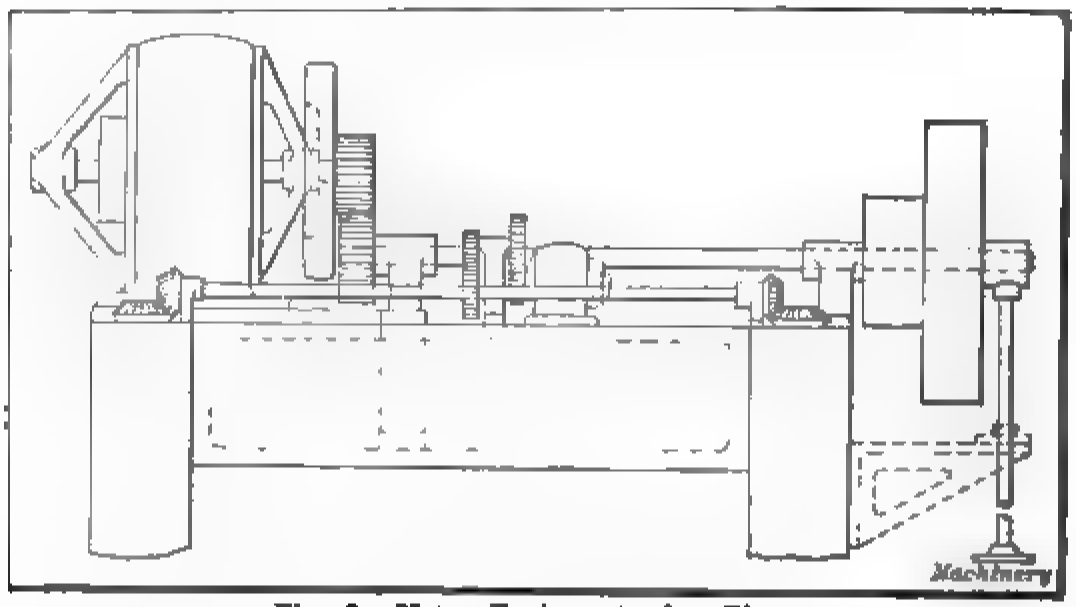


Fig. 9. Motor Equipment of a Planer

the slower running countershaft, the flywheel effect is much increased. It is also well to provide the driving pulleys with extra heavy rims for the additional flywheel effect that they will produce. On slotters it will usually be found convenient to place the motor on a bracket on the side of the frame, and employ a gear drive, while shapers may be either geared or chain-driven, or belt-driven by using an idler as shown in Fig. 10

The remarks regarding the power requirements for constant-cutting tools apply with equal force to this class of machines.

The figures in Table VII are based on the use of two tool-heads and a return speed having a ratio to the cutting speed of about 3 to 1. If more than two heads are used, or if the planer has a longer bed than that given, the horsepower should be somewhat increased.

In addition to the motors employed for operating the tools of the above classes, there are a number of uses for auxiliary motors as will

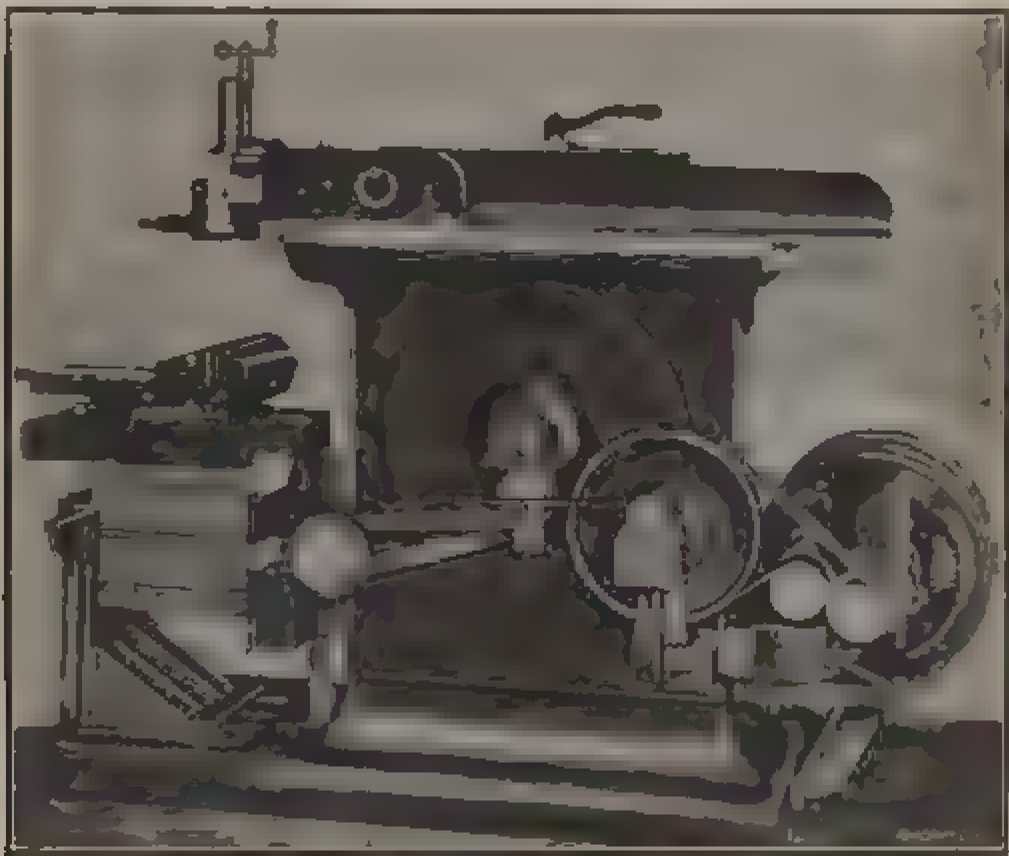


Fig. 10. Motor Equipment of Belt-driven Shaper

be noticed in some of the illustrations. In Fig. 3 is shown an auxiliary motor used for raising and lowering the table of a horizontal boring machine, while Figs. 9 and 11 show similar motors employed for elevating and lowering the cross-rails of a large planer and boring mill, respectively. On large lathes auxiliary motors are often used for moving the tailstock along the bed, and they may also be arranged for turning the turret heads on heavy turret lathes.

Series motors only are used for these purposes, as they are always started under full load, and have their speed regulated by armature control. No rules can be laid down for the power of these auxiliary motors, but the requirements are comparatively small, from 2 to 5 horsepower covering all of the above cases except for the very largest tools. The time of duty is very short. The drives are invariably by means of gearing to the operating shaft, one set of reducing gears frequently being needed to reduce the speed of the motor sufficiently. These motors should never be belted, for if the load should be thrown off by breaking the belt, they will run up to a dangerously high speed, and may be badly damaged. Another type of auxiliary motor is shown

in Fig. 11, where it is used to operate the slotting attachment of a large boring mill. Such a motor should be compound wound and the data relative to slotters are applicable for such motors.

TABLE VII. AVERAGE POWER REQUIREMENTS OF PLANERS

Width between Housings, Inches	Length of Bed, Feet	Horsepower	Width between Housings, Inches	Length of Bed, Feet	Horsepower
84	18	20 to 25	42	10	8 to 10
72	16	15 to 20	30	8	6 to 7½
60	12	10 to 15	20	6	4 to 5

TABLE VIII. AVERAGE POWER REQUIREMENTS OF SHAPERS (SINGLE HEAD)

Stroke, Inches	Horsepower	Stroke, Inches	Horsepower
16	3 to 4	24	3 to 5
18	2 to 3	30	5 to 7½

TABLE IX. AVERAGE POWER REQUIREMENTS OF SLOTTERS

Stroke, Inches	Horsepower	Stroke, Inches	Horsepower
10	4 to 5	24	10
12	5 to 6	30	10 to 16
18	7½		

Controllers

For use with motors on machine tools the drum-type controller is most satisfactory, as it has sufficient mechanical strength to withstand the rough usage to which it is liable to be subjected, at the same time being completely enclosed so that all current-carrying parts

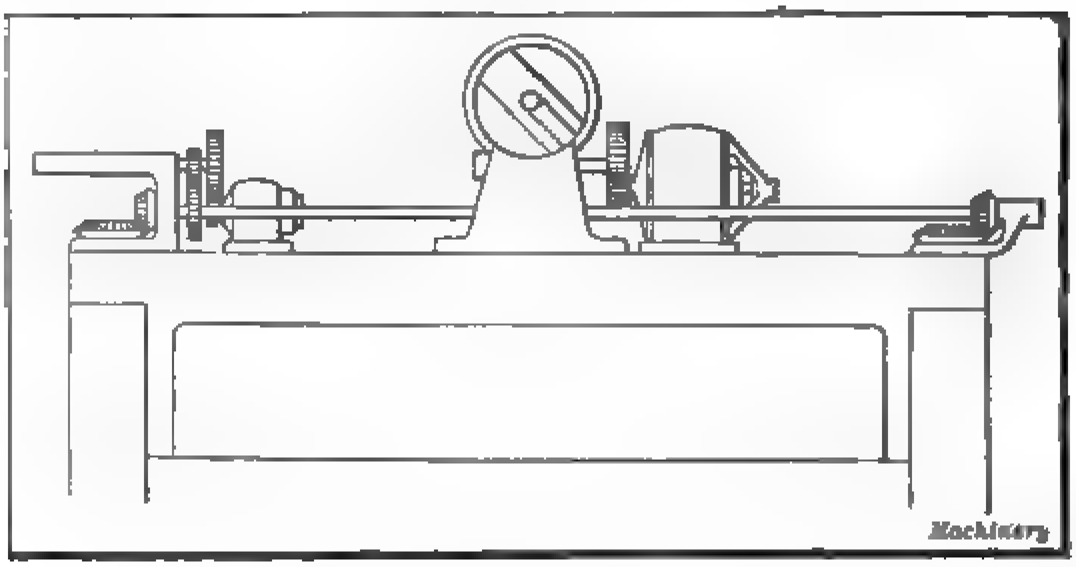


Fig. 11. Auxiliary Motors on Large Boring Mill

are fully protected from dirt and chips and from external injury. Drum controllers are built for both armature and field controlled motors as well as for combined control. They may be either reversing or non-reversing, as desired. When used with motors having a 3 to 1 speed range, obtained by field control, they will ordinarily contain about twenty speed steps. In some sizes the necessary resistance is mounted on the back of the drum, while in others it is

supplied as a separate unit which is connected to the drum by wiring.

The controller should be mounted on the tool at any point to best suit the convenience of the operator. In the case of long lathes a good arrangement is to mount a handle on the lathe apron, and this, by means of gears and shafts can readily be arranged to operate the controller when mounted on the end of the lathe bed.

The resistance, if separate, should be mounted near the controller in order to economize in wiring, but it should be so placed as to be exposed to the air and at the same time protected from dirt and cuttings from the tool. Do not cover up the resistance or place it inside of the tool frame, but select some place above the table of the tool, away from the path of the chips.

Methods of Applying Motors to Machine Tools

In a paper on the Economy of the Electric Drive in the Machine Shop, read at the April, 1910, meeting of the American Society of Mechanical Engineers, Mr A L. De Leeuw reviewed the conditions which must be considered in connection with the equipment of a machine shop with electric drive. In conclusion he gave a general idea of the mode of application of motors to machine tools, the selection of motors for different classes of tools, and the lines along which economical results may be expected. The following abstract of these conclusions will undoubtedly be of interest to mechanics in general.

Bench and Speed Lathes

Bench lathes should be driven from a countershaft attached to the wall or bench and driven in turn by a motor Any kind of motor except a series-wound or heavily compounded motor will do. The object of the motor drive is to get the machine in the best possible location without regard to the location of the lineshafting. A number of these machines may be driven by a common lineshaft, which in turn is driven by a motor.

Speed lathes should be driven from a countershaft located under the lathe, or by a direct-connected motor. In the latter case a variable-speed motor is to be preferred, if direct current is available Motor drive is recommended when the machine is used in the assembling department, as the machines may then be placed where they are most needed, the crane service would also interfere with countershafts. There will be no material gain, if the machines are to be used for ordinary shop operations.

Engine Lathes

Various methods of driving engine lathes by motors are in use Some makers furnish motor-driven engine lathes as standard equipment. Some have a headstock with a limited number of speeds, and depend on a variable-speed motor to fill out the speeds of the lathe. Others apply a constant-speed motor, or one with a limited amount of variation, to an all-geared headstock In general, the use to which this class of machines is put in the shop would to group

drive. There is no material advantage in the individual motor drive, if the machines are used for regular manufacturing operations, except where the location demands individual drive.

Heavy Engine Lathes, Forge Lathes, Etc.

Heavy engine lathes, and lathes of similar types should be driven by a direct-connected motor. The motor should be direct-current, as these machines are too heavy to permit a convenient all-gear drive. If no direct current is available and there is only one machine of its class in the shop, and this is used for an occasional job only, an alternating-current motor could be used, leaving a wide gap in the speeds. If these machines are used for manufacturing purposes, it would pay to install a small synchronous connector. The speed range in the motor does not need to exceed two to one, though a wider range is better if obtainable without complications or great expense. The position of the motor should be low, as the vibrations in the motor-support have a decided influence on the capacity of the machine, as well as on the repair bill. The output of this class of machines may easily be increased from 20 to 25 per cent by motor drive. Further advantages of the motor drive are the possibility of placing the machine in the line of the routing of heavy work, and of placing it immediately under the traveling crane. This latter object may be reached with a belt-driven machine by placing the headstock under the gallery, if the construction of the shop lends itself to this arrangement, but the same convenience as that of the motor drive cannot be obtained.

Axle and Wheel Lathes

It is of the greatest importance that axle lathes and car and driving wheel lathes should have the highest possible efficiency, and the most convenient location. These machines are mostly used in locomotive and car repair shops, where time saved does not mean merely the saving of wages, but each day gained means an added day in the earning capacity of the engine or car. It is, therefore, important that these machines be motor-driven whenever installed in a railroad repair shop, though this does not mean that they should not be so driven if used for manufacturing. Direct current should be used. The economy of the motor drive should not be figured in increased output, but in reduction of time required to repair an engine or car.

Chucking Lathes

Generally speaking, there is little reason why a chucking lathe should be motor-driven. Most chucking lathes are provided with the necessary mechanism to shift speeds quickly. A few types handling large work may be motor-driven to advantage, though practically the only advantage lies in the fact that small gradations in speed can be thus obtained. Such machines, therefore, require a variable-speed motor.

Automatic Screw Machines

Small automatic screw machines are generally group-driven. Large machines may be individually motor-driven to good advantage. The

larger sizes have generally one or two speeds for one piece of work, though these speeds may be varied when the machine is reset for a new piece of work. The speed given to the machine must naturally be proportional to the largest diameter to be turned, or in other words, to the size of stock used. This will reduce the speed for some of the operations, such as drilling and reaming, far below the economical speed. The amount of time saved by the application of the variable-speed motor may be considerable. Where the construction of the machine permits, two motors, one for feed and one for speed, would give still better results. In all cases variable-speed motors should be used.

Drill Presses and Boring Machines

The only reason why the sensitive drill should be individually motor-driven is that it is often used in an assembling department, where height of ceiling and crane service would make a belt drive awkward or impossible. Most sensitive drills have, in themselves, all the speeds required for their work, so that any type of motor will be adaptable. The motor may either be directly applied to the machine or may drive a countershaft on a stand; or it may be placed on the floor by the side of the machine, in case the machine carries its own set of cones or other variable-speed device.

Generally speaking, the upright drill is used for manufacturing operations and does not require frequent changes of speed. There are, however, many exceptions, for instance, where upright drills are used to do all the operations on a piece by means of a jig. In this case frequent changes of tools, and, therefore, of speeds, are required, and an individual motor drive, whether direct-connected to the machine or operating on the countershaft, is of the greatest benefit. No great benefit can be derived from a constant-speed motor with this type of machine. Radial drills may be considered to present the same requirements as upright drills. There is an additional reason why radial drills should be motor-driven—they are often used in the neighborhood of the assembling floor.

When the work for boring machines is specialized and the machines perform only one operation, there is no good reason why motor drive should be preferred to belt drive. Where, however, the machine is used for a multiplicity of operations, such as drilling, boring, reaming and facing, a motor drive is beneficial if a variable-speed motor is used. The range of speed of the motor should be as wide as possible, so that no gears may have to be shifted for the entire set of operations on a single hole. Especially where a boring machine is used for facing, this variable speed will be found highly economical.

Grinders

Grinders, in general, require so many various movements driven from countershafts that it is hardly possib[illegible] motor directly to the machine, the best that ca[illegible] the countershaft to the machine and drive t[illegible]ing on

the floor or on a bracket attached to the machine. In isolated cases it would be well to have one or more motors, each controlling a single operation, attached directly to the machine.

Planers, Shapers, Slotters

Planers in general are not benefited by the application of a motor, as the motor only complicates the difficulties of a planer drive. However, large planers which must be placed under a crane give better results when motor-driven on account of the facility of handling the work. Another possible advantage when using a variable-speed motor and controlling the speed of the motor at the end of the stroke is that much higher return speeds can be obtained in connection with any desired cutting speed. What is true of planers is also true of shapers and slotters. Local conditions may make it advisable to drive them individually by motor, but generally speaking, there are no great advantages to be gained with this drive.

Milling Machines

The larger sizes of knee-and-column type machines, if motor-driven, will give the best results if the motor is of the variable-speed type, especially where these machines are used for gang work. This is due to the fact that the speed of the mills is dependent on the largest cutter in the gang, while the feed is dependent on the smallest cutter, not counting the limitations due to the nature of the work. It is therefore important that the speed should be as close to the permissible limit as possible. When applied to this type of milling machine, the motor should be as low down as possible, as vibrations in the machine have a marked effect on the quality of the finish. In practically all cases the planer type of milling machine should be motor-driven, in order that it may be located under a crane. It is not so very important, however, whether the motor is of the constant-speed or variable-speed type.

Punches, Bending Rolls, Shears, etc.

This class of machinery, used largely for boiler, bridge, structural iron and ship-building work, is generally placed in high shops and under cranes, and in locations and directions most convenient for the routing of the work. The shops in which it is placed are generally large and contain a relatively small amount of machinery, so that the amount of transmission gearing required is large in proportion to the amount of machinery. It is for this reason advisable in almost all cases to drive this class of machinery by an electric motor, which, of course, does not need to be of the variable-speed type.

CHAPTER II

WIRING ON MOTOR-DRIVEN MACHINERY

Electrical wiring on the motor-driven machines furnished by even the best manufacturers is too often poorly arranged and inefficiently installed. This is because the wiring is not considered when the machine is designed. Its installation is usually left to some workman who does the best he can. The wiring and arrangement of the control apparatus should be laid out in the drafting-room This chapter discusses the best methods of machine wiring, describes the materials used, and gives concrete directions, rules and tables for wiring motor-driven machinery.

One industrial corporation which purchases many motor-driven machines incorporates the following clauses in the specifications for all such equipments:

1. The machine manufacturer shall mount the motor and controlling devices on the machine so that they shall form a part thereof, and shall wire between them as hereinafter noted.

2. The controlling apparatus shall be conveniently arranged for manipulation by the machine operator.

3. All wiring shall be installed in accordance with the regulations of the National Electrical Code.

4. All wiring shall be carried in wrought-iron conduit or in metal conduit fittings. These shall be firmly attached to the frame of the machine.

5. So far as possible, all "live" bare metal parts shall be enclosed with metal covers.

It was found desirable to makes these requirements because of the awkward practice prevailing in this respect among machine builders. Frequently, the builder of the motor-driven machine, although he carefully mounted the motor and arranged the drive between the machine and the motor, would fail to mount the motor-starter or controller on the machine. If he did mount it on the machine, in the great majority of cases he would either provide no wiring between the motor and the controller, or install the wiring in such a careless, unbusinesslike manner that it would have to be reinstalled. Usually, the machine builder makes an extra charge for arranging the wiring in accordance with the above specifications; but it was found that the work was done better and more cheaply by the builder than by the wire-men at the plants where the machines were installed. At the present time, when motor-driven machinery is so generally used, machine builders are paying more attention to the electrical details, but there is still much to be desired. In the followin[illegible] some practical information that may be of va[illegible]

desiring to arrange and install the wiring on their machines as efficiently as possible. It is believed that good wiring will be appreciated by the purchaser.

Rule No. 1 in the specifications given states that when the machine is direct-driven the motor and controller should be considered as a part of the machine. Obviously, they are just as much so as is a gear. If possible, the complete equipment should be shipped so that, after setting up, it will only be necessary for the plant electrician to run a pair of wires to put the machine in service. For large machines, which must be dismantled for transportation, the motor and controlling equipment must be shipped separately, and it may be necessary to dismount the conduit carrying the electrical conductors; but if the wiring has been properly connected and the conduit strapped to the machine in the erecting shop, it can easily be reinstalled. Thus, cranes, which have complicated wiring, can be taken apart, shipped, reerected and rewired with very little difficulty.

The desirability of the requirements of Rule No. 2 is so obvious as to need no discussion.

Rule No. 3 requires that all wiring be installed in accordance with National Electrical Code regulations. Standard fire insurance policies require that the electrical work in all plants having insurance protection be installed in accordance with these regulations. It has taken many years to mold the regulations into their present excellent form, and they are revised constantly to keep abreast with the advances in the art. It is therefore essential that machines which are to be installed in plants carrying fire insurance, be wired in accordance with the Code. Even if insurance is not carried, it is advisable to follow these rules, as they outline a substantial and safe method of wiring. A copy of The National Electrical Code will be supplied free to any one making request to the local Fire Underwriters' Inspection Bureau or to the Underwriters' Laboratories, Chicago, Ill.

Rule No. 4 requires that wiring be installed in wrought-iron conduits or in metal conduit fittings. It costs several times as much to run wiring in metal conduit (the properties of conduit are given in Table XII) as to arrange it without mechanical protection. However, it is only the first cost of conduit wiring that is high. When placed in conduit the wiring is done once for all; there is no future trouble from broken wires, grounds or short circuits, due to abraded insulation. When arranged with conduit wiring, the machine is easier to keep clean and looks neater. The conduit fittings (which will be described later) are used at points where wires issue from the conduit or where a turn in the conduit run is necessary and it is not desired to bend the conduit. In general construction, they somewhat resemble screwed pipe fittings, but they are always arranged with removable covers so that the wire is easily accessible. Conduit and fittings are attached to machine frames with either pipe straps (Table XV) or machine screws, as will be described.

Rule No. 5 requires that all "live" bare metal parts be enclosed within metal covers. It is usually feasible to enclose these parts.

Such enclosure prevents metallic chips from forming grounds or short circuits and renders shock to attendants impossible. With the voltages at which machine motors are usually operated, a shock is not often fatal, but one hears of cases where men have been killed from contact with 220-volt circuits. At any rate, an electrical shock is unpleasant, and if there is a possibility of receiving one the attendant is likely to be cautious and waste time. Fire risk is reduced by enclosing "live" parts. Although the Underwriters do not require enclosure they commend it. The electrical manufacturers appreciate the demand for enclosed apparatus, and it is now possible to buy standard starters and controllers, for nearly all applications, that are well protected and so arranged that conduit wiring can be readily installed.

Wire for Motor Application

The size of wire to use for transmitting electrical energy (in low-voltage work such as that involved in industrial-plant wiring) is determined by two requirements, *viz.*, the cross-sectional area must be large enough to carry the current required without getting too hot, but must not be so large as to cause an excessive drop in voltage—electrical pressure—and consequent energy loss. However, the distances involved in wiring machinery are so short that the latter requirement may be disregarded altogether. The only demand is, then, that the wire be big enough to obviate excessive heating.

The National Electrical Code specifies that all concealed wires shall be rubber-insulated and, in addition, that all wires carried in conduit shall have a double-braid covering. All standard rubber-covered wires used for voltages above 10 and below 600 have the same thickness of insulation. Copper wire is almost universally used for interior wiring. Therefore, if the voltage of the motor is below 600, wire for the installation should be specified, for example, thus: No. 6 National Electrical Code Standard, 0-600 volts, double-braid, stranded, copper wire. The size of wire, and whether it is to be solid or stranded, is determined, as will be explained, by the horsepower output of the motor.

So that wire in service will not be dangerously overheated, the Underwriters have specified a certain safe current-carrying capacity for each size of wire and for wires having different insulating materials. In Table X are given the safe current-carrying capacities for all sizes of rubber-covered wire that the machine builder is likely to use. The sizes listed are all commercial ones and are, as a rule, readily obtainable. When the current or amperes taken by any motor is known, the size of wire to be used can be ascertained from Table X. Although Nos. 18 and 16 wires are listed in the table, the Underwriters do not permit the use, for applications such as herein treated, of any wire smaller than No. 14. It will be noted that the wires between No. 18 and No. 8, inclusive, are tabula[illegible] ose larger than No. 8 as "stranded." Solid wi[illegible] conductor, while the conductor in strandec[illegible] several or many wires of relatively smal[illegible] are sometimes called cables. It is the us[illegible]

to specify that wires larger than No. 8 be stranded, because, if solid, they are too stiff to be handled and pulled into the conduit readily. Solid wires can be obtained, if desired, in sizes much larger than No. 8 and these are much used in "open-work" wiring. The numbers of wires in a strand given represent the practice of some manufacturers, but other manufacturers have different standards. They vary little, however, from those shown. As a rule, it is not desirable to specify the "number of wires in strand" when ordering, as the dealer may

TABLE X. SPECIFICATIONS FOR WIRE AND CONDUIT ON MOTOR-DRIVEN MACHINERY

Double-braid, Rubber-covered, 0 to 600 Volts, N. E. C. S. Copper Wire, N. E. C. S. Wrought-iron Conduit

	Number of Wire, B. & S. Gage	Area of Wire, Circular Mills	Number of Wires in Strand	Safe Current-carrying Capacity, Amperes	Size of Conduit, Inches: 1 Wire in Conduit	2 Wires in Conduit	3 Wires in Conduit
Solid Wire	18	1,624	Solid	3	½	½	½
	16	2,583		6	½	½	½
	14	4,107		12	½	½	½
	12	6,530		17	½	¾	¾
	10	10,380		24	½	¾	1
	8	16,510		33	½	1	1
Stranded Wire	6	26,250	7	46	½	1	1¼
	5	33,100	7	54	¾	1¼	1¼
	4	41,740	7	65	¾	1¼	1¼
	3	52,630	7	76	¾	1¼	1¼
	2	66,370	19	90	¾	1½	2
	1	83,690	19	107	1	1¼	2
	0	105,500	19	127	1	2	2
	00	133,100	19	150	1	2	2
	000	167,800	19	177	1¼	2	2½
	0000	211,600	19	210	1¼	2	2½
	....	200,000	19	200	1¼	2	2½
	....	250,000	37	235	1¼	2½	2½
	....	300,000	37	270	1¼	2½	3
	....	350,000	37	300	1½	2½	3
	....	400,000	37	330	1½	3	3
	....	450,000	37	380	2	3	3½
	....	500,000	61	390	2	3	3½
	....	550,000	61	420	2	3½	4
	....	600,000	[illegible]	450	2	3½	4
	....	650,000	61	475	2	3½	4
	....	700,000	61	500	2	3½	4

not be able to furnish just the stranding designated from his stock. Any stranded wire, for conduit work, will answer the purpose, and the use of stock sizes will obviate delay.

The size of wire to use for machine wiring is determined by the current (amperes) only. The current taken by any motor may readily be computed from rules given in electrical handbooks. If [illegible]
is available, its exact full-load current is, in accordance [illegible]
rule, stamped on its name-plate. If the motor is not [illegible]
load current value, accurate enough for the present [illegible]
from Table XI. It should be understood that the

are averages and may vary somewhat from name-plate ratings. Different makes of motors of the same horsepower have different efficiencies and, with alternating-current motors, different power factors, and both these appreciably affect the amount of current taken. The figures given in Table XI indicate the current in each wire That is, they show the number of amperes flowing through each of the two wires to a direct-current or to a single-phase alternating-current motor, through each of the four wires to a two-phase alternating-current motor, or through each of the three wires to a three-phase alternating-current motor.

Having found the current, in amperes, taken by a motor, the size of wire to be used cannot be selected without first considering another

TABLE XI. APPROXIMATE FULL-LOAD CURRENT (IN AMPERES) TAKEN BY ELECTRIC MOTORS

H.P. of Motor	Direct-current Motors			Alternating-current Motors								
				Single-phase			Two-phase (Four-wire)			Three-phase (Three-wire)		
	110 Volts	220 Volts	500 Volts	110 Volts	220 Volts	500 Volts	110 Volts	220 Volts	500 Volts	110 Volts	220 Volts	500 Volts
1	9	5	2	14	8	3	6	3	2	7	4	2
2	16	9	4	25	13	5	12	6	3	13	7	3
3	27	13	6	34	17	8	17	8	4	19	9	4
5	42	21	9	53	26	12	25	13	6	31	15	6
7½	60	31	13	75	38	16	39	20	8	45	22	9
10	77	37	18	93	49	22	44	23	11	51	25	13
15	111	57	26	....	....	....	66	34	15	77	39	17
20	151	76	34	....	....	....	89	44	20	103	52	23
30	226	114	49	....	....	....	135	68	30	155	78	33
40	303	152	67	....	....	....	179	90	39	205	107	46
50	369	183	83	....	....	....	205	102	44	237	119	52
75	551	277	123	....	....	....	310	155	69	356	179	78
100	737	369	162	....	....	....	409	206	91	473	236	105
150	1114	556	245	....	....	....	618	308	137	711	356	157
200	1475	736	326	....	....	....	820	410	183	940	472	210

point. National Electrical Code, Rule 8b, reads, in part, as follows: "The motor leads or branch circuits must be designed to carry a current at least 25 per cent greater than that for which the motor is rated. Where wires under this rule would be over-fused in order to provide for the starting current, as in the case of many alternating-current motors, the wires must be of such size as to be properly protected by these larger fuses." The machine builder has no means of knowing what size fuses the purchaser of his appliance will use, so ·est thing he can do, ordinarily, is to provide wires capable ᵒ 25 per cent more current than the full-load rating on. The wire size is, then, selected on this basis. that a 10-H P., 220-volt., three-phase motor 'o Table XI, we find that this motor takes

about 25 amperes when operating at full load. To allow for a 25 per cent excess current, in accordance with the Code rule, an estimate is made thus: $25 \times 1.25 = 31$ amperes (about). Referring to Table X, a No. 8 (solid) wire which has a safe carrying capacity of 33 amperes is the smallest that can be used.

The insulation on rubber-covered wire deteriorates very rapidly under the action of heat, so if it is necessary to install conductors where they will be subjected to high temperatures, wire having "slow-burning" insulation should be used. Such wire, if enclosed, must be (according to the Code) in "lined" conduit. This conduit is described under the following heading.

Conduit for Motor Application Wiring

Wrought-iron conduit is merely standard-weight steel, or possibly in some cases wrought-iron pipe, which has been thoroughly cleaned to remove burrs and scale, and then either enameled or coated with zinc. Conduit which meets the requirements of the National Electrical Code and which has been approved by an Underwriters' inspector, is called National Electrical Code standard conduit or N. E. C. S. conduit. In Table XII are given the principal dimensions of commercial N. E. C. S. conduit, elbows and couplings. Conduit is furnished only in lengths of ten feet. Electrical conduit is threaded with standard pipe threads and standard-weight screwed pipe fittings will fit it.

In addition to the "unlined" conduit, described above, a "lined" conduit is manufactured which has a relatively thick insulating lining. The lined conduit is seldom used as it is more expensive than the unlined and the latter has given entire satisfaction. The insulating lining appears to be unnecessary, as the rubber insulation on standard wire provides excellent protection.

Although its use would be prohibited by the Underwriters, there is really no objection to using commercial wrought-iron pipe instead of conduit for wiring machines. Such pipe should be carefully cleaned inside and out and every precaution taken to make sure that there are no burrs or slivers on the inside of the pipe which might cut insulation on wires. After the pipe is painted, it is almost impossible to distinguish it from conduit.

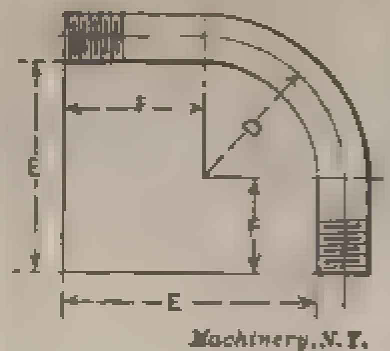
Conduit elbows are formed from conduit to the dimensions indicated in Table XII. The smaller sizes of conduit can be bent cold to any desired contour, but it requires some skill to do the bending. Conduit-bending machines are obtainable and their installation pays if there is much wiring to be done. Both power- and hand-operated types are manufactured. Couplings for conduit are exactly the same as screwed couplings for standard-weight pipe, except that the former are either enameled or coated with zinc and have a better finish.

After determining the proper size of wire to use for supplying energy to a given motor, the size of conduit to carry it can be sel- from Table X. The sizes theretabulated, for the different wire, have been chosen as the result of much experience with wiring. They are sufficiently large to allow wires to be dra

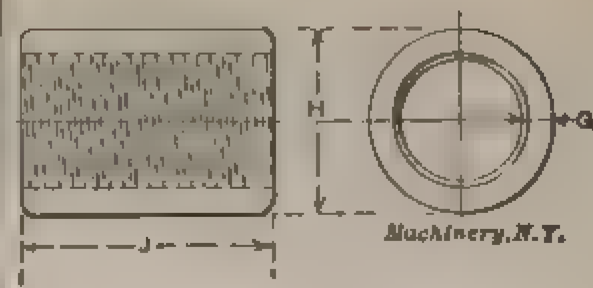
TABLE XII PROPERTIES OF CONDUIT, ELBOWS AND COUPLINGS

CONDUIT

ELBOWS



COUPLINGS



Nominal Size of Conduit	A Outside Diameter		B Inside Diameter		C Thickness of Walls		Nominal Weight, Pounds per Foot	D Radius of Center Line	E Offset	F Length of Str'ght Portion	Weight of 100 in Pounds	G Thickness	H Outside Diameter	J Length	Weight of 100 in Pounds
	Actual	Fraction to Nearest 64th	Actual	Fraction to Nearest 64th	Actual	Fraction to Nearest 64th									
1/2	0.84	27/32	0.623	5/8	0.109	7/64	0.85	4 1/4	7 1/2	2 9/16	78	1/4	1 5/32	1 5/16	15 1/4
3/4	1.05	1 3/64	0.824	53/64	0.113	7/64	1.12	5 1/4	9 1/4	3 1/4	182	13/64	1 13/32	1 7/16	25 1/2
1	1.315	1 21/64	1.048	1 3/64	0.134	9/64	1.67	5 3/4	10 1/8	4 1/8	200	11/64	1 11/16	1 1/2	40 1/2
1 1/4	1.66	1 21/32	1.380	1 3/8	0.140	9/64	2.24	7 1/4	11 1/2	3 7/16	300	11/64	2	1 13/16	57 1/2
1 1/2	1.90	1 29/32	1.611	1 39/64	0.145	9/64	2.68	8 1/2	12 5/8	3 9/16	415	3/16	2 7/32	2 1/16	71 1/2
2	2.375	2 3/8	2.067	2 1/16	0.154	5/32	3.61	9 1/2	15 1/4	4 9/16	700	1 1/32	2 11/16	2 5/16	132
2 1/2	2.875	2 7/8	2.468	2 15/32	0.204	13/64	5.94	10 1/2	17 3/4	5 11/16	1139	15/64	3 7/32	2 11/16	185
3	3.50	3 1/2	3.067	3 1/16	0.217	7/32	7.54	13	19 3/8	4 1/8	1885	23/64	4 1/32	3	300
3 1/2	4.00	4	3.548	3 35/64	0.226	7/32	9.00	15	21	4	2100	1/2	4 1/2	3 1/8	400
4	4.50	4 1/2	4.026	4 1/32	0.237	15/64	10.66	16	32 1/2	4 1/2	2160	1/4	5 1/32	3 1/8	412

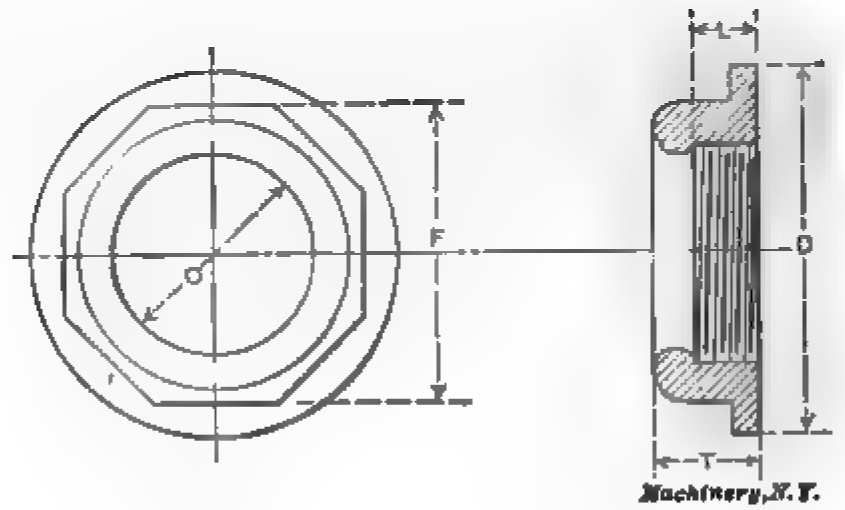
All dimensions in inches. All tubes are 10 feet long, threaded at both ends and furnished with a coupling. These dimensions were taken from manufacturers' tables and from samples.

out without the application of excessive force. It is a common error to choose a conduit size so small that the wires must be pulled in with blocks and tackle. If this is done, the insulation is likely to be injured and withdrawal may be impossible.

Conduit Fittings and Sundries

Where wires emerge from conduit ends, the Code requires that provision be made so that a possible burr on the inside of the conduit will not abrade the insulation on the wires when they are being drawn

TABLE XIII. DIMENSIONS OF CONDUIT BUSHINGS



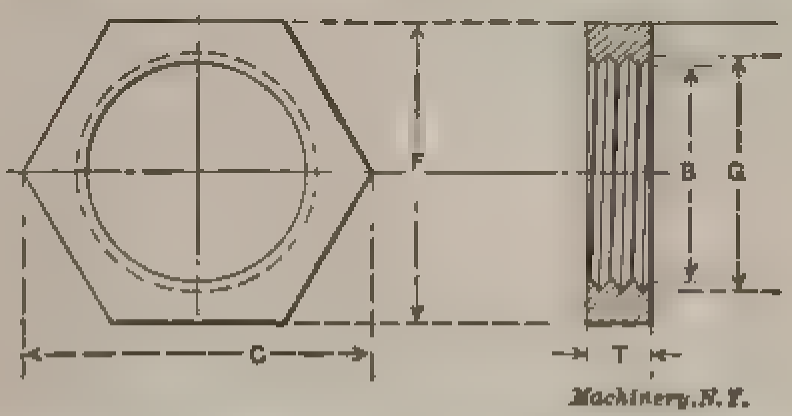
Thomas and Betts Bushings. All Dimensions taken from Samples. All Dimensions in Inches

Size of Conduit	F	D	O	T	L
3/8	[illegible]	27/32	[illegible]	[illegible]	[illegible]
1/2	[illegible]	1 1/32	[illegible]	[illegible]	[illegible]
3/4	1 1/[illegible]	1 1/4	3/4	[illegible]	[illegible]
1	1 [illegible]	1 [illegible]	[illegible]	[illegible]	[illegible]
1 1/4	1 [illegible]	1 [illegible]	1 5/16	[illegible]	[illegible]
1 1/2	1 [illegible]	2 5/[illegible]	1 [illegible]	[illegible]	[illegible]
2	2 [illegible]	2 [illegible]	1 [illegible]	[illegible]	[illegible]
2 1/2	2 7/8	3 [illegible]	2 [illegible]	[illegible]	[illegible]
3	3 [illegible]	3 [illegible]	2 [illegible]	[illegible]	[illegible]
3 1/2	4 [illegible]	4 7/16	3 [illegible]	1	[illegible]
4	4 [illegible]	5 1/16	3 [illegible]	1 1/16	[illegible]

in or out. Conduit ends may be protected either by a bushing, such as shown in the engraving accompanying Table XIII, or by a fitting of one of the types shown in Fig. 14, equipped with a porcelain cover, Fig. 12. The bushing should be used when the conduit terminates within an enclosed outlet, junction, or panel box (see Fig. 13) which may be made of either cast or sheet iron. The dimensions given in Table XIII will prove useful in indicating what clearances are required for screwing the bushing on the end of the conduit and will also assist in determining the locations for the conduit holes.

Outlet boxes usually have unthreaded holes for the conduit, as indicated in Fig. 13, but where a waterproof installation is essential,

TABLE XIV. DIMENSIONS OF CONDUIT LOCK-NUTS



Thomas and Betts Lock-nuts. All Dimensions taken from Samples. All Dimensions in Inches

Size of Conduit	Threads per Inch	B	G	F	C	T
$\frac{3}{8}$	18	0.568	0.658	1	$1\frac{1}{8}$	$\frac{5}{32}$
$\frac{1}{2}$	14	0.701	0.815	$1\frac{1}{16}$	$1\frac{7}{32}$	$\frac{5}{32}$
$\frac{3}{4}$	14	0.911	1.025	$1\frac{1}{4}$	$1\frac{7}{16}$	$\frac{5}{32}$
1	$11\frac{1}{2}$	1.144	1.288	$1\frac{1}{2}$	$1\frac{23}{32}$	$\frac{3}{16}$
$1\frac{1}{4}$	$11\frac{1}{2}$	1.488	1.627	$2\frac{1}{16}$	$2\frac{5}{16}$	$\frac{3}{16}$
$1\frac{1}{2}$	$11\frac{1}{2}$	1.727	1.866	$2\frac{1}{4}$	$2\frac{9}{16}$	$\frac{3}{16}$
2	$11\frac{1}{2}$	2.223	2.339	$2\frac{11}{16}$	$3\frac{1}{8}$	$\frac{7}{32}$
$2\frac{1}{2}$	8	2.620	2.820	$3\frac{1}{4}$	$3\frac{3}{4}$	$\frac{1}{4}$
3*	8	3.241	3.441	$4\frac{11}{32}$	$4\frac{11}{16}$	$\frac{11}{32}$
$3\frac{1}{2}$	8	3.738	3.938	$4\frac{1}{4}$	$5\frac{1}{16}$	$\frac{3}{8}$
4	8	4.234	4.434	$5\frac{1}{4}$	$5\frac{7}{8}$	$\frac{5}{16}$

* This size is octagonal.

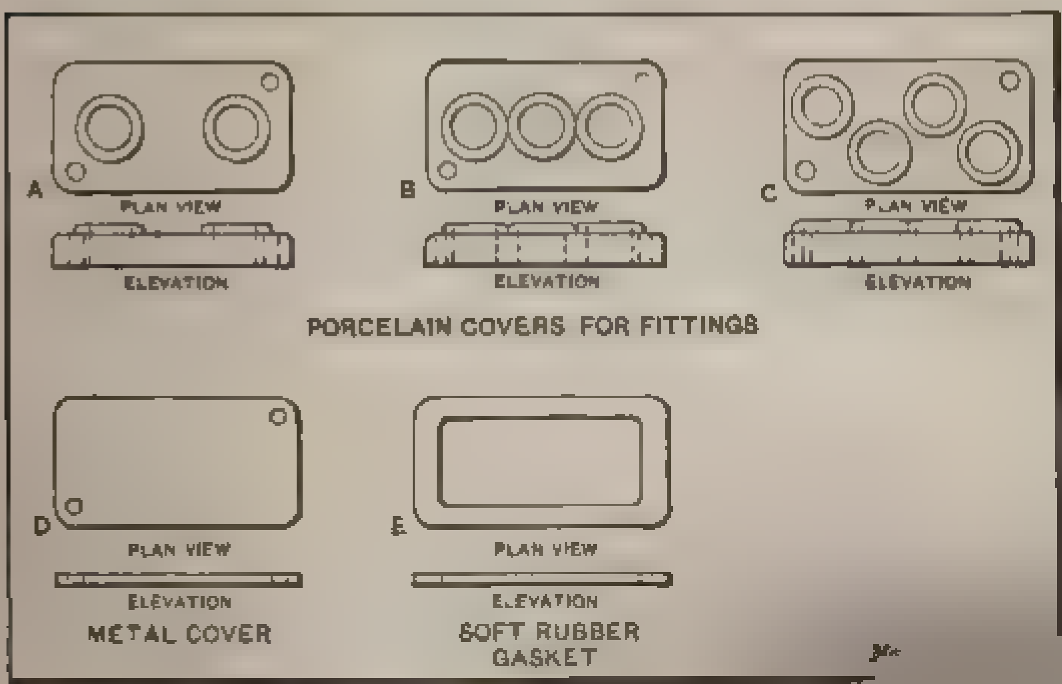


Fig. 12. Covers and Gasket for Conduit Fittings

the holes should be threaded. When the holes are unthreaded, a lock-nut (shown with Table XIV) is run on the end of the conduit and, after the bushing is screwed to position, the lock-nut is turned up snugly against the side of the box, binding the conduit firmly in position. It should be understood that the dimensions given in Tables XIII and XIV for bushings and lock-nuts are accurate for only one manufacturer's line. There are several different makes available, but all will measure approximately the same as those shown.

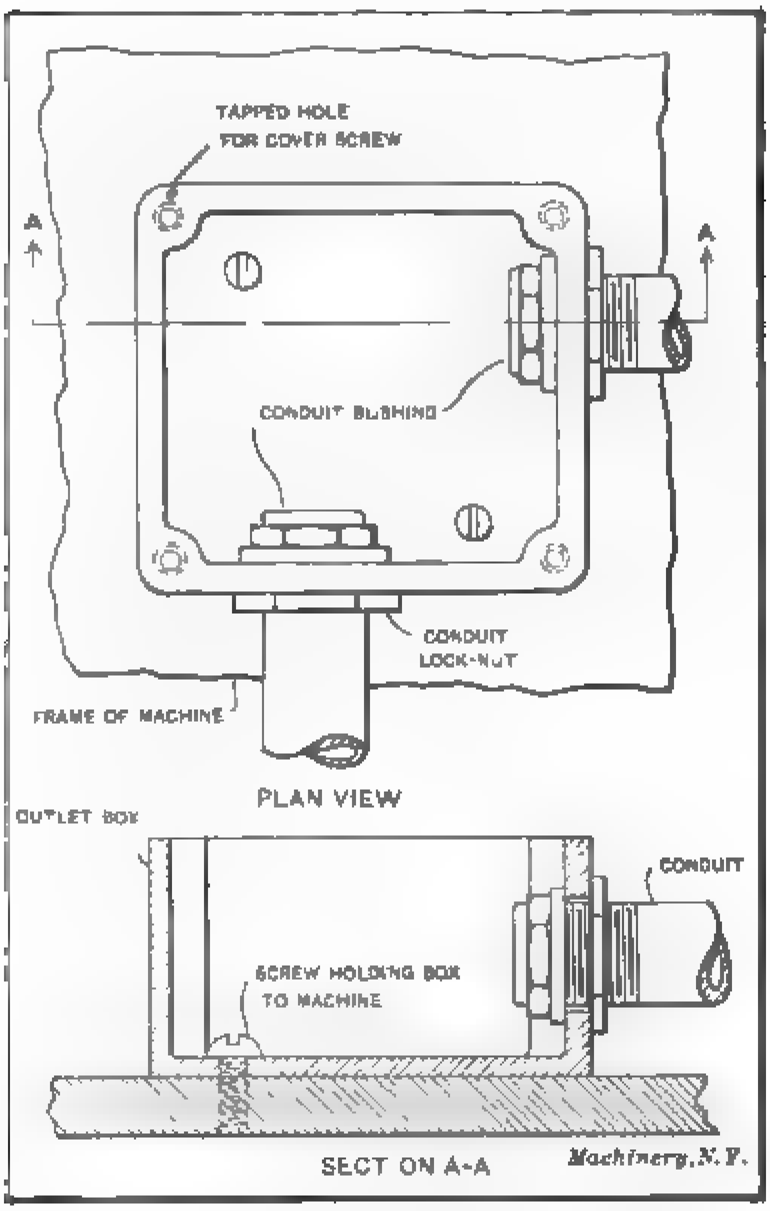


Fig. 13. Outlet Box Mounted on Machine

The application of conduit fittings can best be shown by an example. In Fig. 15 is illustrated a motor-driven open-side planer with the wiring between the starter and the motor neatly carried in conduit. At the motor terminal the conductors issue through a fitting, which is of the type shown in Fig. 14 at *C*, equipped with the cover shown in Fig. 12 at *B*. The conduit fittings are so made that any style of cover of a given pipe size will fit any cast-iron fitting of corresponding pipe size. The covers are held on with brass screws. In Fig. 17 is shown an arrangement of fittings that might be used with the type of starting panel shown in Fig. 15, if the motor were located below instead of above the panel. It will be noted that where "elbow" fittings (*G* and *H*, Fig. 14) are arranged with metal covers, they are effectively used at turns in the conduit run, instead of bends or wrought-iron elbows. Fig. 18 illustrates further applications of conduit-fitting elbows.

A very convenient feature of the fittings shown in Fig. 14 is the provision of a headless set-screw in the throat. By means of this set-screw it is possible to secure a conduit end firmly in a fitting even if the threading on the conduit is faulty or if, because of a

bend in the conduit, it does not set up tightly in the fitting, when in its proper position. In this type of fitting, conduit can be secured without being threaded at all. The set-screw provides ample attachment, if conduit and fittings are firmly fastened to a supporting surface, as they usually are on machinery. Nor is it necessary to thread conduit running into fittings like that in Fig. 16. An unthreaded end of a conduit length is inserted in the nipple, the nut is tightened, and the conduit is secured. The threaded portion of the nipple is split and tapered. These fittings possess several advantageous points. Being of sheet-steel, they are unbreakable. The fact that

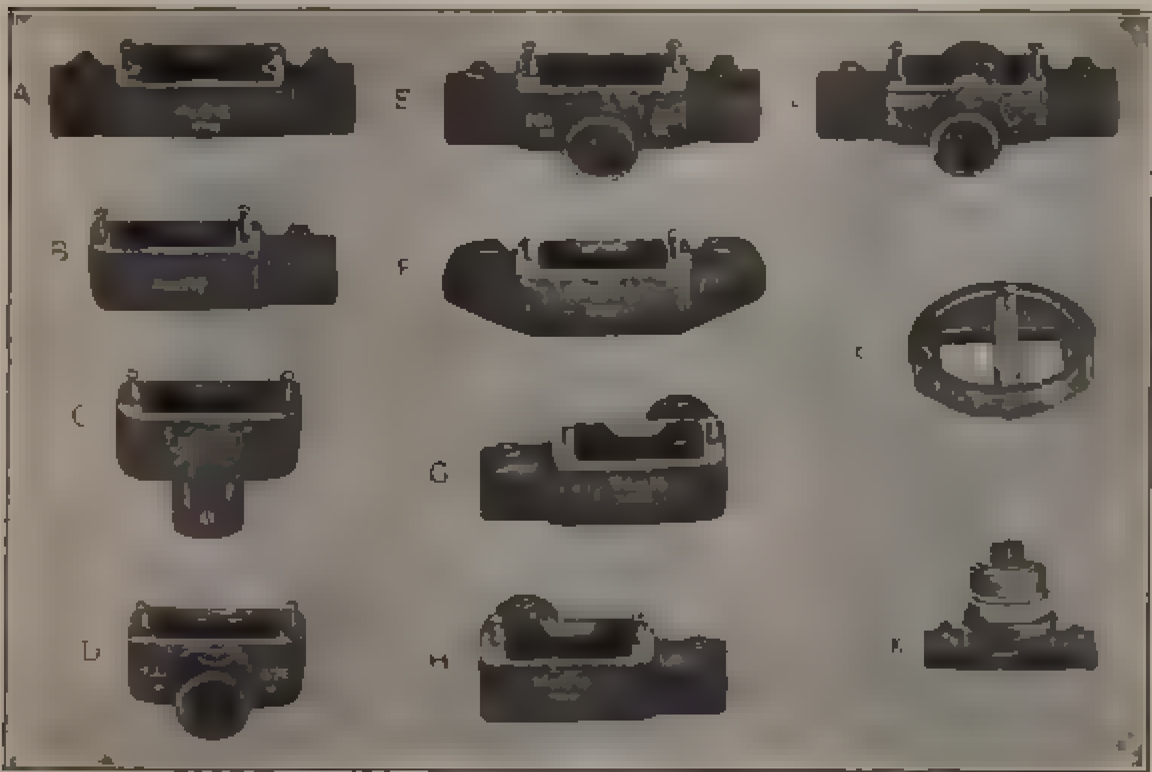


Fig. 14. Types of Cast-iron Conduit Fittings

each fitting has several "knock-out" holes makes possible a great number of combinations from a comparatively small stock of fittings and covers.

Supporting Conduit Wiring

Obviously, conduit carrying conductors should be so securely supported that there can be no chance of its being displaced under reasonable conditions. Pipe straps, formed from sheet-steel and then galvanized, such as those shown with Table XV, are most frequently used for supporting conduit, as shown in Figs. 15, 17 and 18. The dimensions given in Table XV will be found useful in making clearance allowances and in determining the locations for the tapped holes for the round headed machine screws, with which the straps are fastened. The dimensions in Table XV are accurate only for the lines of certain manufacturers, but will be approximately correct for all makes.

Another good method of supporting conduit runs is by fastening the fitting to the machine frame with machine screws, as shown in Figs. 13 and 19. The screws pass through a hole drilled in the bottom of the fitting and down into a hole tapped in th[illegible]ame.

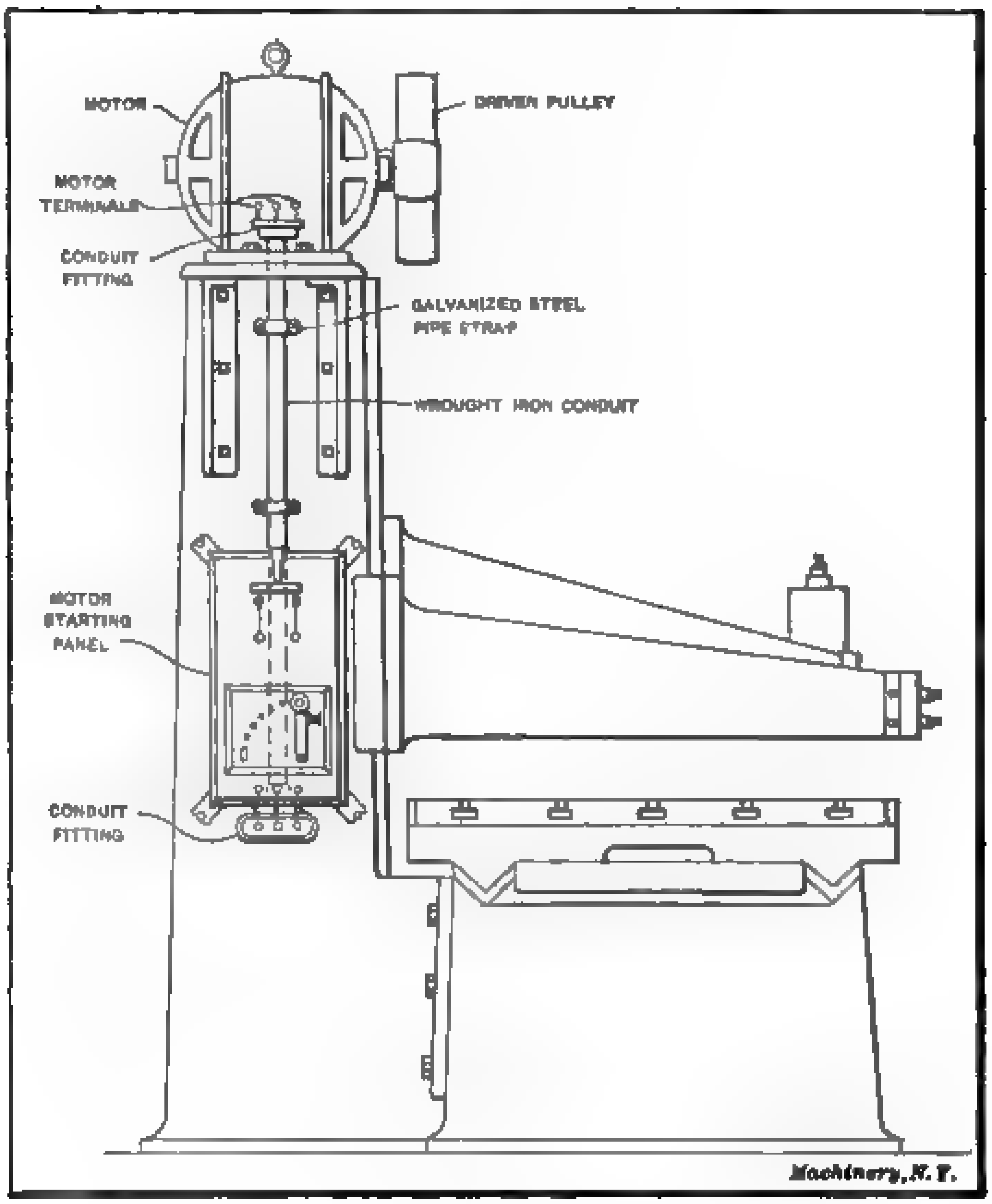


Fig. 15. Open-side Planer with Well-arranged Wiring

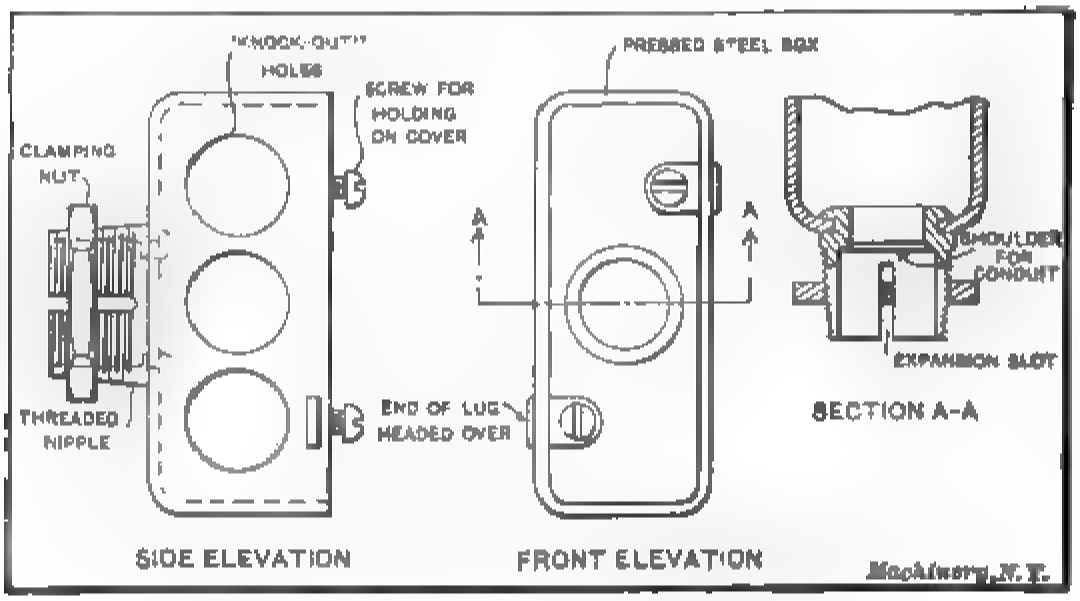


Fig. 16. Details of Typical Pressed-steel Fitting

It is often feasible to support a complete conduit installation by this method and thereby entirely avoid the use of pipe straps. This sort of a job presents a neat appearance.

Motors Arranged for Conduit Wiring

When it is specified that the "motor shall be arranged for conduit wiring," certain motor manufacturers will provide, without extra charge, a metal terminal box, with a removable cover, around the motor terminals. A motor so arranged is shown in Fig. 18. Such a terminal box permits of the best possible installation, and through its presence a conduit fitting, like that at the motor in Fig. 15, can be dispensed with. A hole is provided in the terminal box and the conduit is terminated with a bushing in the hole.

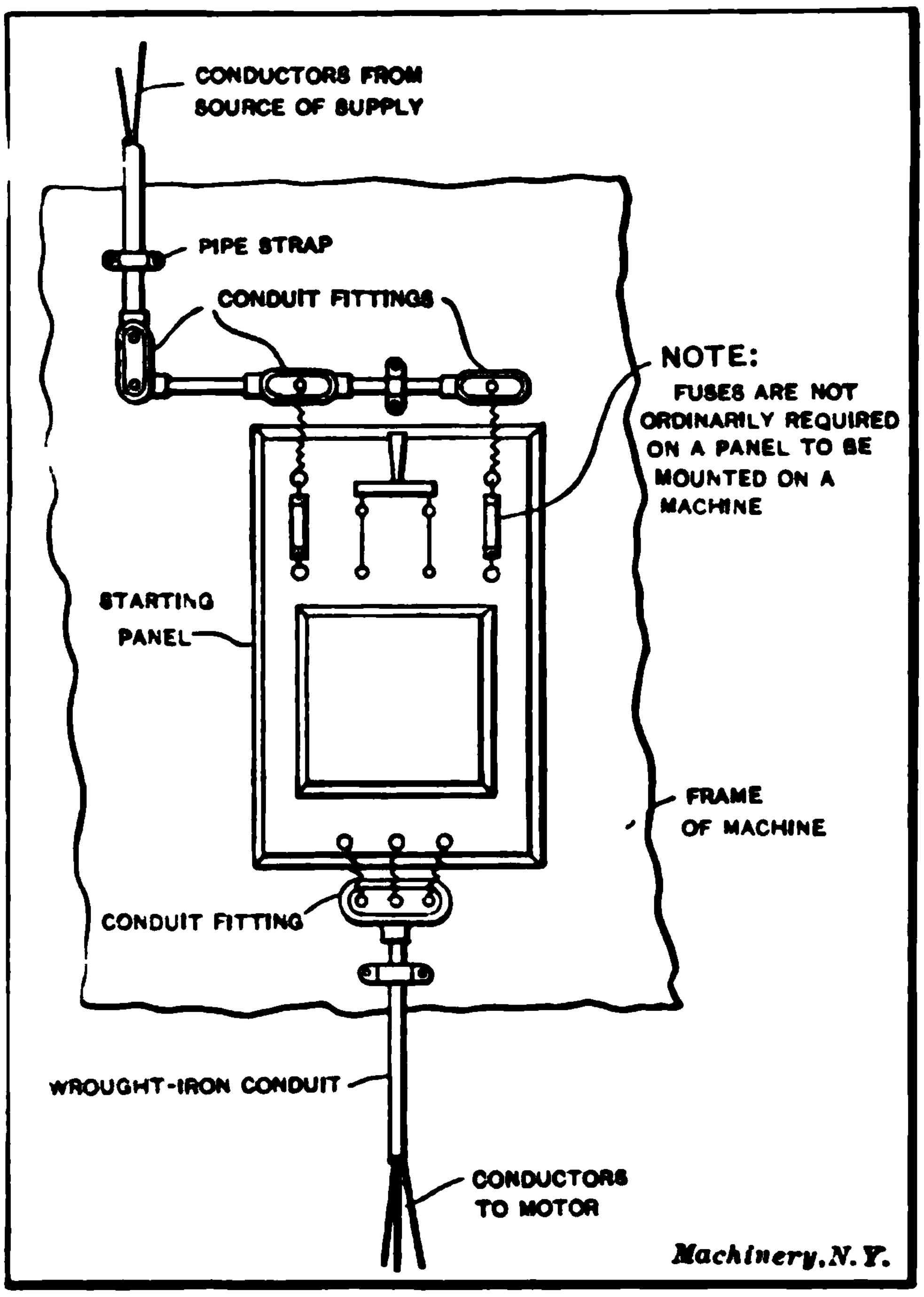


Fig. 17. A Neatly Wired Starting Panel

Switches

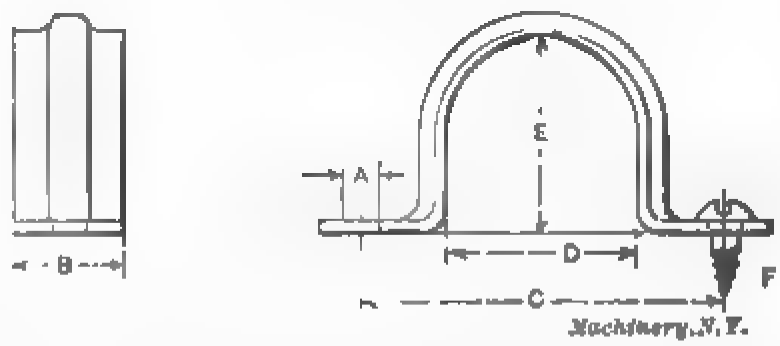
It is required by the National Electrical Code that every motor and starting box be protected by a double-pole cut-out (fuses or circuit breaker) and controlled by an indicating switch that plainly indicates whether the circuit is open or closed. For motors exceeding in capacity ¼ horsepower, a double-pole switch is required, but a single-pole switch may be used for smaller ones. It is always advisable, however, to use the double-pole type, as through its use both sides of a circuit are rendered dead when the switch is open.

For handling currents up to 20 amperes, or thereabout, the best switch to use is of the indicating-snap type, shown in Fig. 20. This type can readily be obtained as either single-pole, for direct-current and single-phase alternating-current motors, or triple-pole for three-phase motors. All "live" parts are effectively enclosed in a formed sheet-metal cover (Fig. 20) which is lined with an insulating material. By unscrewing the composition handle, the cover can be quickly re-

moved for making connections. Wires enter the switch through holes in the back of the porcelain base. A revolving dial, bearing the legends "On" and "Off," indicates whether the switch is open or closed.

An indicating-snap switch mounted on a conduit fitting as shown in Fig. 21 makes a rugged and safe switching combination. All wires and "live" parts are completely enclosed. Some manufacturers make conduit fittings especially designed for carrying switches;

TABLE XV. DIMENSIONS OF PIPE STRAPS



All Dimensions taken from Samples. All Dimensions in Inches

Nominal Size of Pipe	A: Diameter of Screw Hole	B: Width of Strap	C: Distance between Centers of Screw Holes	D: Width of Opening	E: Height of Opening	F: Size of Wood Screw to Use (No. × in.)	Approximate Cost per 100	Approximate Number per Pound
$\frac{1}{4}$	0.20	[illegible]	1 [illegible]	[illegible]	[illegible]	8× [illegible]	$0.40	75
[illegible]	0.20	[illegible]	1 [illegible]	[illegible]	[illegible]	8× [illegible]	0.45	72
$\frac{1}{2}$	0.20	[illegible]	1 [illegible]	[illegible]	[illegible]	8× [illegible]	0.50	40
$\frac{3}{4}$	0.22	[illegible]	2 [illegible]	1 [illegible]	1	10× [illegible]	0.75	29
1	0.22	[illegible]	2 [illegible]	1 [illegible]	1 [illegible]	10× [illegible]	1.00	21
$1\frac{1}{4}$	0.22	[illegible]	2 [illegible]	1 [illegible]	1 [illegible]	10×1	1.25	18
$1\frac{1}{2}$	0.22	[illegible]	3	2	1 [illegible]	10×1	1.50	14
2	0.22	1	$3\frac{1}{4}$	$2\frac{1}{2}$	2 [illegible]	$10\times1\frac{1}{4}$	2.00	12
$2\frac{1}{2}$	0.25	$\frac{7}{8}$	4 [illegible]	$2\frac{3}{4}$	2 [illegible]	$11\times1\frac{1}{4}$	2.75	6

but an equivalent fitting may be assembled, as shown in Fig. 14 at *K*, with the components *A* and *J*, or with *J* and any other piece shown in Fig. 14.

For handling currents above 20 amperes, open-knife switches are commonly used. The open type is used because (so far as the writer is aware) no enclosed knife switch is regularly manufactured. These open switches are best mounted close to the motor starter. Controllers and starters, as will be outlined later, can be purchased with the line switches mounted directly on them, as indicated in Figs. 16 and 17. Such combinations are called starting or controlling panels.

In all of these examples of knife-line-switch and controller applications, it was evidently deemed unnecessary by the designer to enclose the switches and controllers. If enclosure is desirable (and as many view it, there are few cases where it is not) a cover for a knife

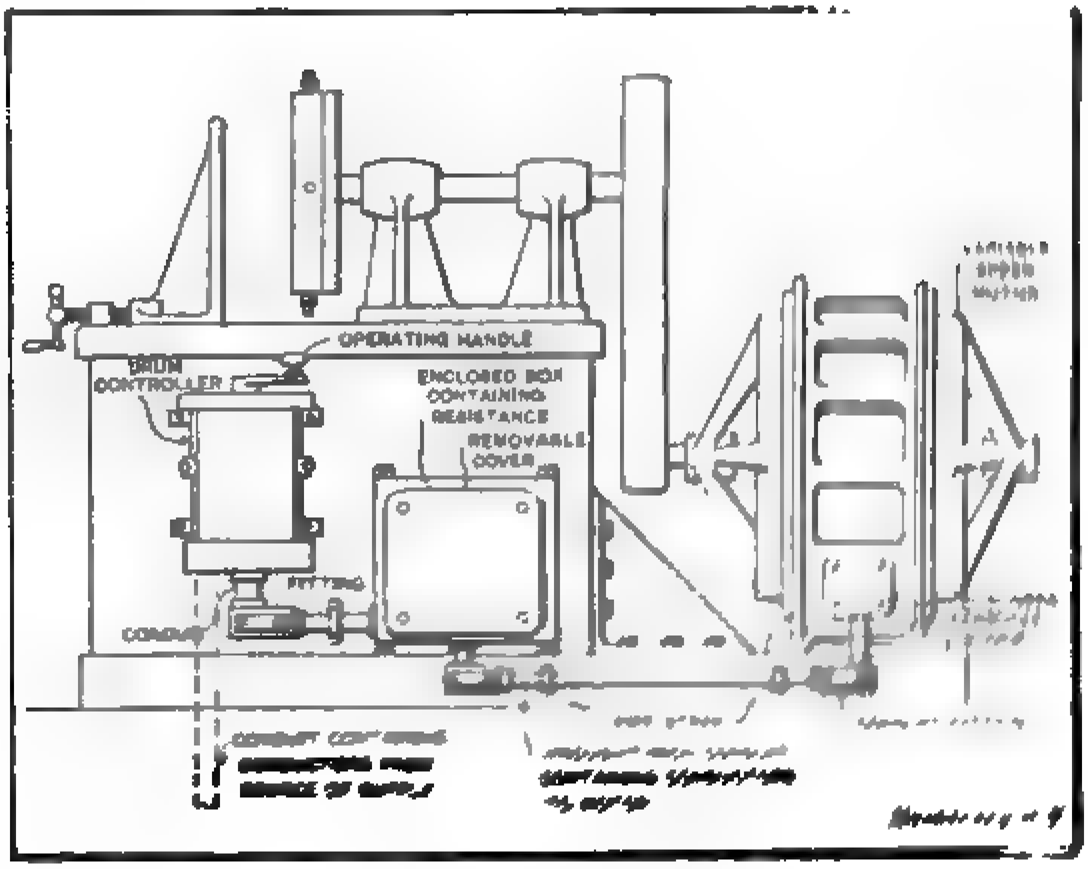


Fig. [illegible]. Machine Equipped with Drum Controller

switch can readily be constructed from sheet [illegible] as suggested in Fig. 22. As will be described subsequently, [illegible] are often used on motor-driven machines, making [illegible] unnecessary.

While a cut-out is required by the [illegible] controller combination, it is not [illegible]

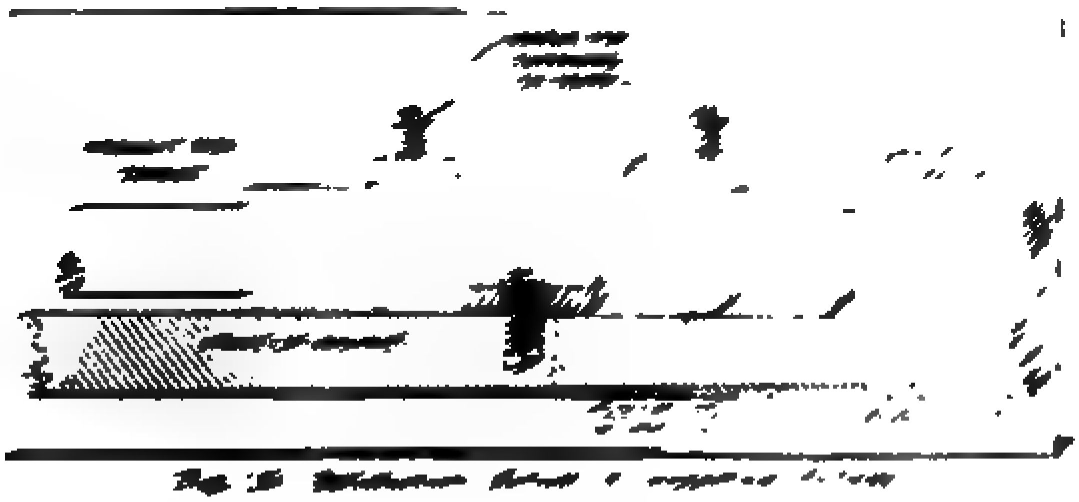


Fig. [illegible]

chine, [illegible]

[illegible]

[illegible] Fig. [illegible]

[illegible]

inasmuch as the branch wires are usually smaller than the main wires and the Code requires the installation of a cut-out wherever there is a decrease in wire size.

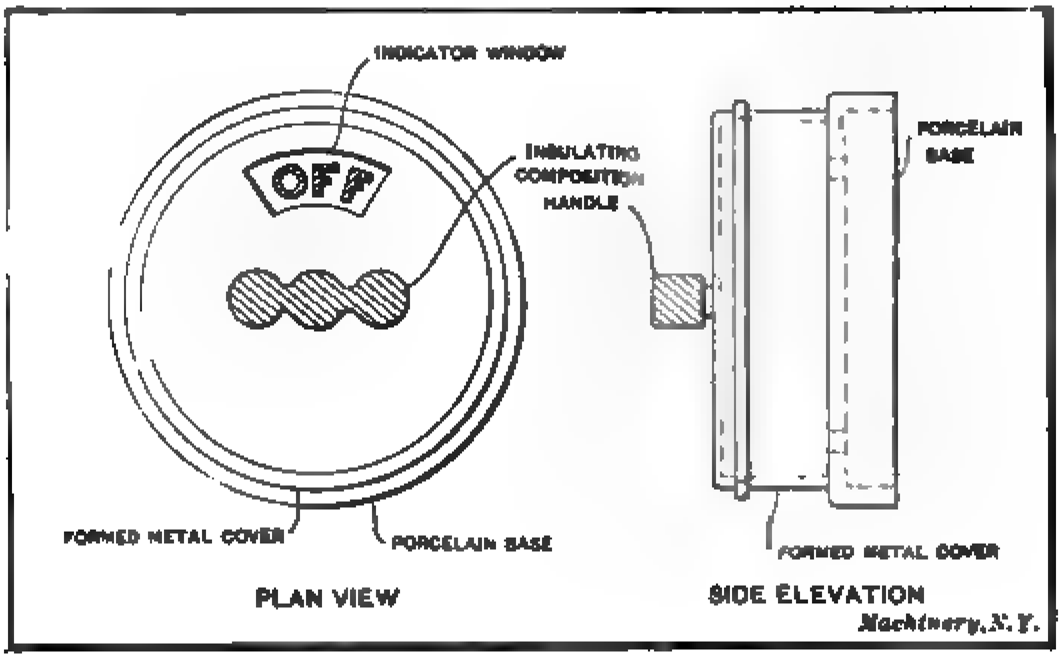


Fig. 20. Indicating Snap Switch

Motor Controllers and Starters

Motor starters as regularly furnished by the motor manufacturers are of the open type shown in line-cut Fig. 15. By "open type" is

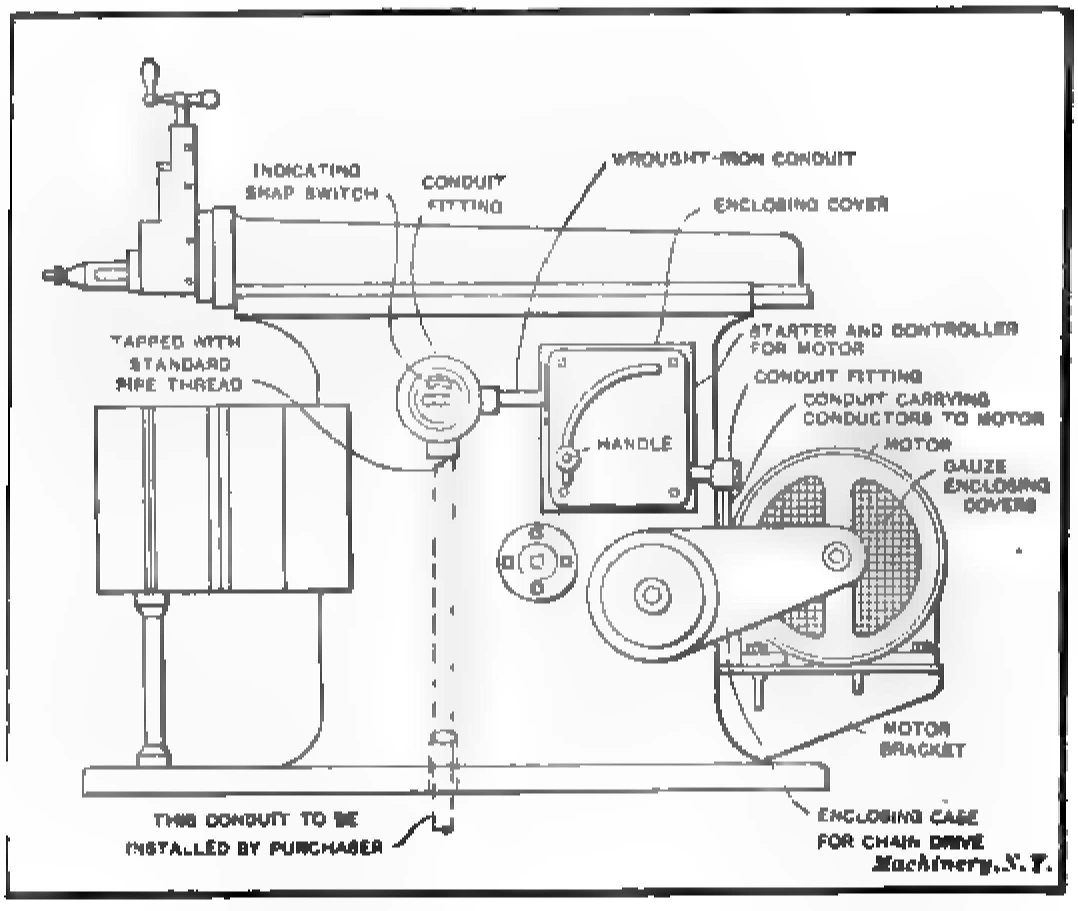


Fig. 21. A Motor-driven Shaper with Completely Enclosed Wiring

meant a type which does not have its "live" parts protected by a cover. These open starters have given and will give entire satis-

faction in places where it is reasonably clean. But some purchasing concerns prefer to have, in so far as possible, all electrical apparatus enclosed, and it is believed that, all things considered, this is usually the most economical method, although the first cost of enclosed equipment is a trifle higher. An enclosed starter is shown in Fig. 21. It consists merely of a standard open starter fitted with a cover which encloses all "live" parts, and has a semi-circular slot for the operating handle. Most of the electrical manufacturing concerns have standardized and are prepared to furnish enclosing covers for their control equipment. Such a cover makes it difficult for the unauthorized to

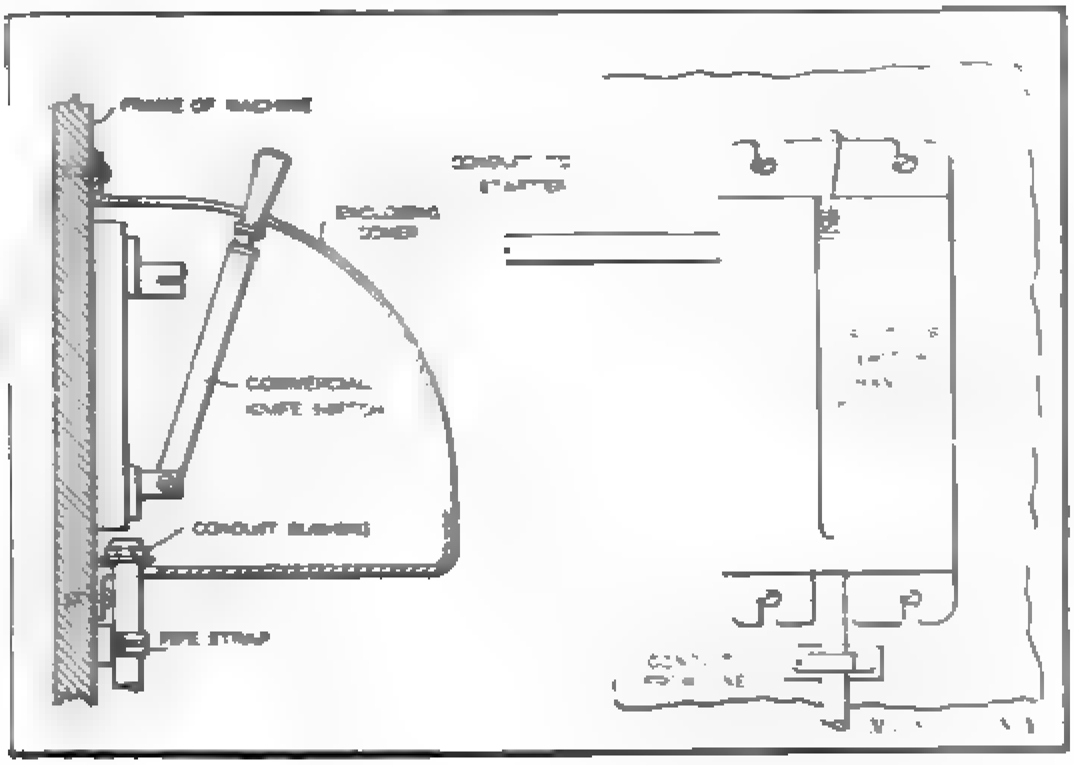


Fig. 22. Enclosing Cover for Knife-switch

tamper with the adjustment of the starter, keeps it clean, eliminates liability to shock and prevents grounds or short circuits due to flying metal chips.

The purchaser of an enclosing cover for a starter should insist that it enclose not only the dial-contacts, but also the terminals on the starter. Certain manufacturers will furnish a cover that will shroud the dial and not the terminals, unless specifically directed as above; *all* bare current-carrying parts should be enclosed.

In Fig. 24 is detailed an excellent enclosing cover that can be applied to standard starters. Instead of being slotted for the operating handle as is the one shown in Fig. 21, a better construction is used. An auxiliary operating handle and arm is mounted on the cover; on the end of this arm is an insulating fork which engages the controller arm when the cover is in its normal position, and thus transmits the movements of the operating handle to the controller arm. The absence of a slot in the cover makes the starter dust-proof. The terminals are completely enclosed and a removable piece that can be taken out altogether, for the admittance of wires, or drilled for conduit, is pro-

vided above the terminals. When this cover is applied to the standard controller the old controller handle is removed.

Sometimes a circuit-breaker is substituted for the switch on a starting panel, as shown in Fig. 25. A circuit-breaker is one type of cut-out. It opens a circuit automatically when a current, of a value for which it is set, flows through it. It can also be opened manually by releasing a catch. Circuit-breakers, of reliable types, are considerably higher in first cost than a switch-fuse combination, but in the long run they are more economical. The reasons for this are: First, fuse renewals, which are relatively expensive, are not required; and second, the cost of labor wasted while fuses are being replaced, is saved.

The panel in Fig. 25 is shown without enclosing covers so that its construction will be apparent; but it is made with covers which expose only the circuit-breaker and starting-rheostat operating handles.

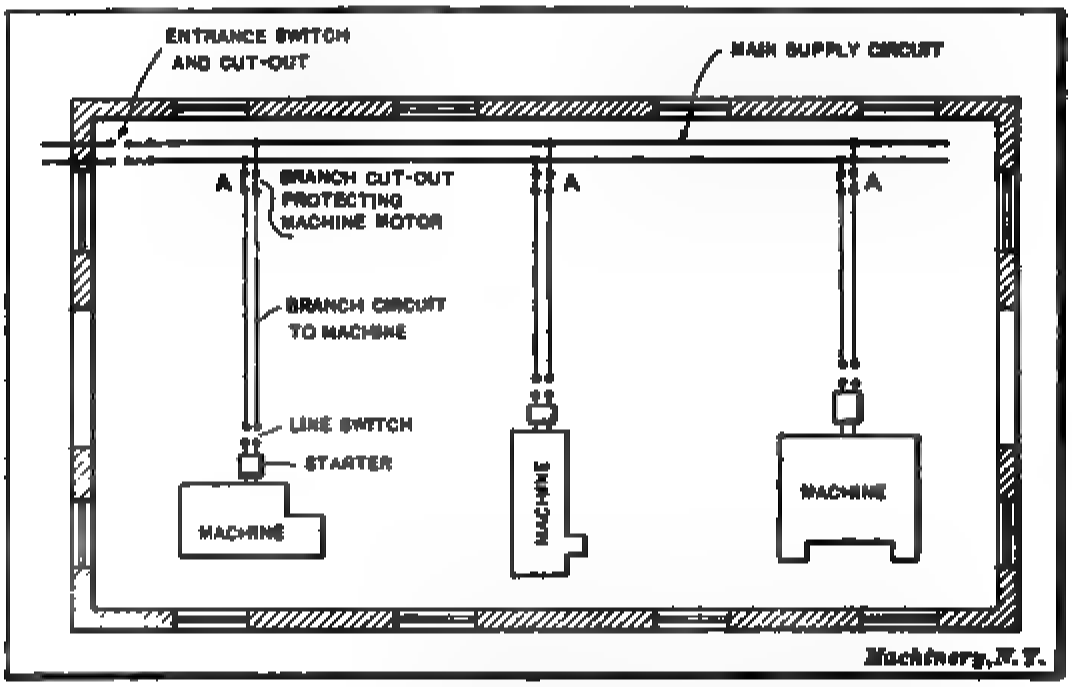


Fig. 23. Wiring Diagram for Motor-driven Machines

Some manufacturers enclose panels like that of Fig. 25 in sheet-metal steel boxes having hinged doors, but this is not a satisfactory arrangement for machinery applications, because, to operate the starter or manipulate the switch, the attendant must open the door. This is awkward and, in case of accidents, when the motor should be stopped without delay, prevents quick action. The consequence is that the door is usually left open or is taken off altogether.

As previously mentioned, motors on machines are frequently protected by branch-fuses located at the supply circuit as shown at A in Fig. 23, and a circuit-breaker or a starting panel provides additional protection. However, the circuit-breaker should be set to trip on a smaller current than will rupture the fuses. The circuit-breaker the brunt of an overload and operates instantaneously, saving th of fuse renewals. As the economies of circuit-breaker applicati becoming better understood they are becoming more popular.

large industrial corporations specify them on every motor starting or controlling panel.

Drum controllers with external resistances are deservedly becoming very popular, particularly for variable-speed control. In Fig. 18 is shown drum-controller applications. The drum controller receives its name from the fact that contact is made between stationary fingers and rotating segments mounted on a drum. All the parts can be made very rugged and can be so arranged as to be readily removable for renewal and repair. The resistance is arranged in a separate frame which can be provided with an enclosing cover and arranged for conduit wiring as shown in Fig. 18. The drum usually contains only the contact-making mechanism. It is believed that a drum con-

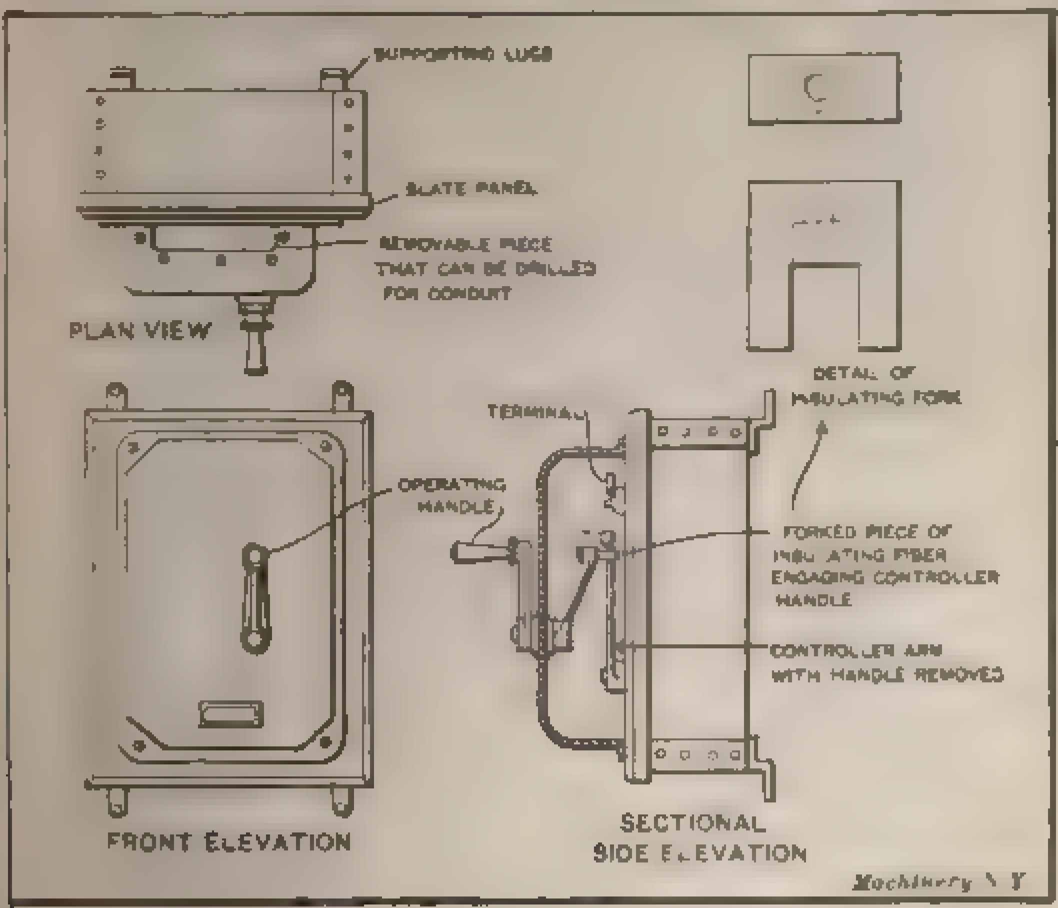


Fig. 24. A Good Enclosing Cover Design

troller is preferable in every way to one of the dial type, which has contact buttons arranged on the face of an insulating panel and a swinging arm to make electrical contact with them.

Often the drum controller is mounted conveniently near the motor at the head of the lathe. The controlling handle, whereby the lathe is started, stopped, or has its speed varied, is attached to and travels with the apron and hence is always handily located for operation. The handle engages with a longitudinally slotted shaft so arranged that when the handle is turned the shaft turns. The shaft extends nearly the entire lengt[illegible]the and motion is transmitted from it to the controller dru[illegible] of sprockets and a chain. It will be noted that th[illegible]over [illegible] controller can be easily removed by unscrewing a coupl[illegible]

Enclosing Motors

Motors can be furnished either open, semi-enclosed or fully enclosed. A fully enclosed motor of a given horsepower and speed costs more than a semi-enclosed or an open one, because a large frame is needed for the enclosed type. The power capacity of a motor depends largely on its ability to dissipate the heat generated within it, and if it is enclosed, the heat is dissipated with difficulty. To reduce the quantity of heat generated, the parts must be proportioned more generously; hence the necessity for larger frames for enclosed motors. Motors seldom need to be fully enclosed unless they are to operate in very dirty places, or in other special cases. A gauze enclosure such as that indicated in Fig. 21 is satisfactory for most machinery applications.

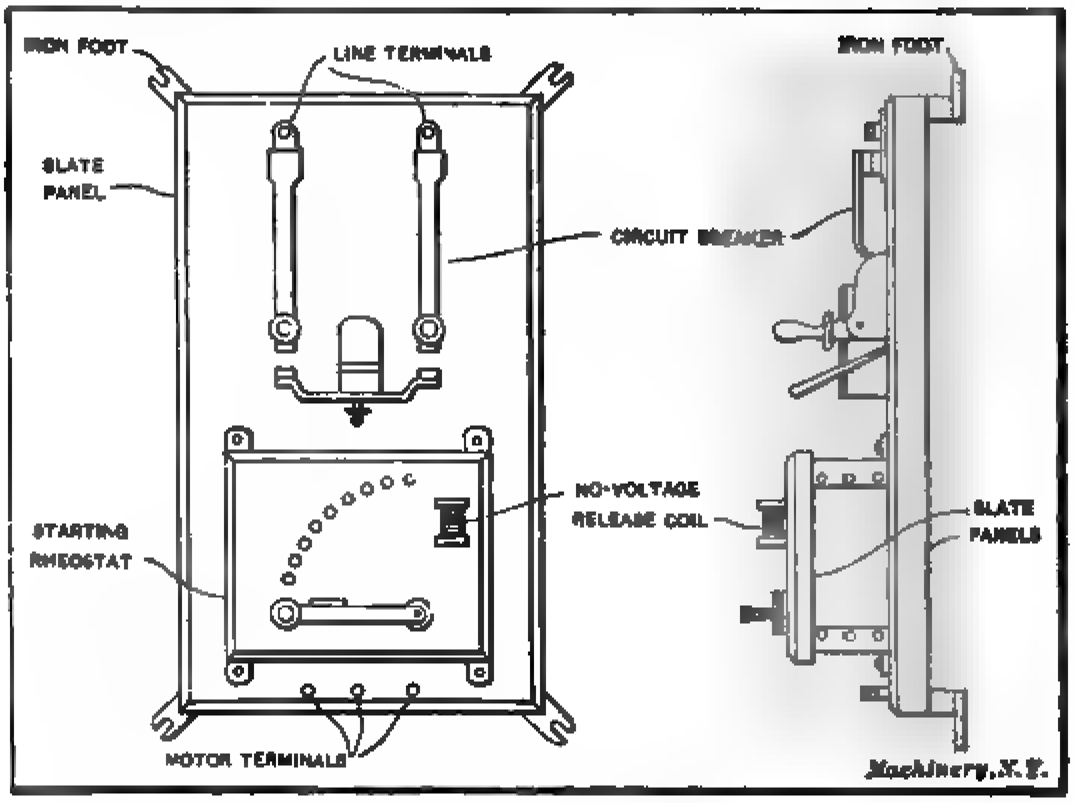


Fig. 25. A Circuit-breaker Starting Panel

Gauze or wire-netting enclosing covers reduce the rating of a motor very little, if any. The use of such covers is advocated on motors for nearly all machine drives.

The Code specifies that the frames of all motors operating at potentials in excess of 550 volts shall be either permanently grounded or else insulated by wooden frames or otherwise. The use of a wooden frame or any other insulating arrangement is not usually feasible, so the almost universal practice is to bolt the motor frame into good electrical contact with the frame of the machine. It devolves upon the purchaser of the machine to see that it is well grounded, either through the conduit conveying the conductors to the machine (the Code requires that the conduit of all conduit wiring systems be grounded) or through a specially provided ground wire connected to the machine. The Underwriters require that special permission be obtained before motors with grounded frames are installed.

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THE MANUFACTURE OF STEEL BALLS

By ROBERT H. GRANT

CONTENTS

CHAPTER I

MAKING THE BALL BLANKS

A review of the history of ball-making would take us back, it is claimed, more than four thousand years. The Chinese, who seem to have made everything first, are supposed to have made balls at that early date. This claim, however, is founded on a mere assumption and not on historical fact. Modern ball-making dates back to about 1870. Bicycles were then used to some extent in England, but as the bicycle was first made with a plain bearing, it was very laborious to propel; later cone bearings were introduced, and while these made the bicycle easier to work, it never became very popular until balls were used in the bearings. The first balls were made by the English workmen in their own homes, as was the custom in those days, by a very primitive method. A bar of steel of the proper size was placed in a chuck in a foot-power lathe. Then a ball was formed on the end of the bar by means of a hand tool, the long handle of which was pressed against the shoulder. The balls were made only a few thousandths of an inch larger than the finished size. They were then hardened and ground. The grinding was done between two cast-iron plates about eighteen inches in diameter. These plates were provided with concentric circular grooves, and the balls were placed in these grooves with oil and emery. The top plate was then revolved by hand; it was removed at intervals and the balls measured until found to be of the proper size. These balls were sold for 12 cents apiece. At the present time balls of the same size, and of a superior quality, can be purchased for 1/7 cent.

First Machines for Manufacturing Balls

The Simonds Rolling Machine Co., of Fitchburg, Mass., was the first company in the United States to engage in the manufacture of balls. This company was manufacturing a machine for making rolled forgings, and as by means of this machine it was possible to roll a very accurate ball, it was decided to start the manufacturing of this product. In Fig. 1 is shown a 3-inch rolling machine of the type mentioned, the size (3-inch) indicating the width of the platens. These platens run in opposite directions, and are operated by racks in the back, which, in turn, are driven by pinions on the driving shaft. The driving shaft extends to the rear of the machine where the driving gears are located. The length of the stroke is changed by the dogs *A*, which can be moved to different positions in a grooved plate, as shown. The rest *B* supports the stock while it is being rolled. The platens make about one hundred strokes per minute.

In Fig. 2 is shown a die for rolling balls on the Simonds machine. This die is held in a shoe which is fastened to the platen. The 30-degree bev[illegible] is knurled so that when the work is rolled, it [illegible] dies, but rotate properly. The

knurling of the beveled face of the dies was one of the most important of the patents obtained by the company in connection with this development. The "invention," however, was incidental. During the early stage of the development of the machine, a workman had been trying to roll a certain piece, but the stock would keep sliding through the machine without rolling. The operator then lost patience and, determined to make the stock roll, took a cold chisel and roughed up

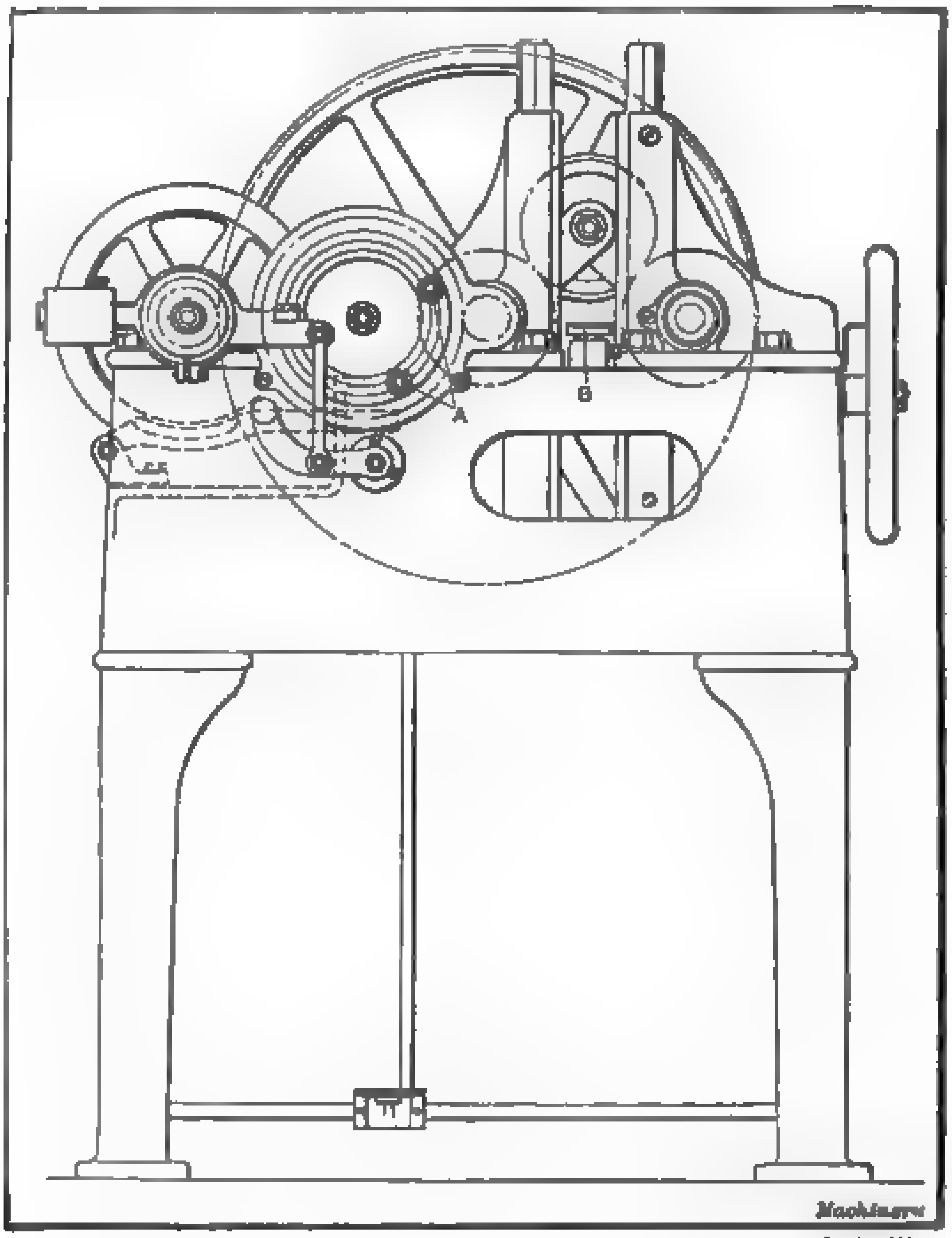

Fig. 1. Machine for Making Rolled Forgings, built by the Simonds Rolling Machine Co., Fitchburg, Mass., Some Twenty-five Years ago

the edges of the die, with the result that the die immediately produced perfect forgings. On the next set of dies made, he used a coarse knurl on the edges of the die to facilitate the proper movement of the stock. This method of knurling was patented in connection with the die, and this patent was considered one of the strongest in connection with rolling processes of this kind.

The method of rolling balls, however, is very wasteful on account of the fact that the stock which revolves over the knurled part of the die is thrown away as scrap. For every ball that is made, a diamond-shaped piece, as shown in Fig. 3, of the same diameter as the stock, has to be made and thrown away. In the illustration referred to, *A* is the stock, *B* is the ball being rolled, and *C* the diamond-shaped piece which is wasted. Hence, it will be understood that this method is very expensive when used for ball-making, although the rolling method of forging can be used to advantage on long articles where the waste is proportionately small.

In rolling methods of this kind there is a decided tendency to "pipe" the stock on account of the difference between the speed at the largest diameter and that at the "centers" of the ball, where, as a matter of fact, the metal is simply crushed and does not roll. Frequently there will then be a hole or pipe right through the center of the ball which will show after the teats at the end have been ground off. As an example of the tendency to pipe, it may be mentioned that

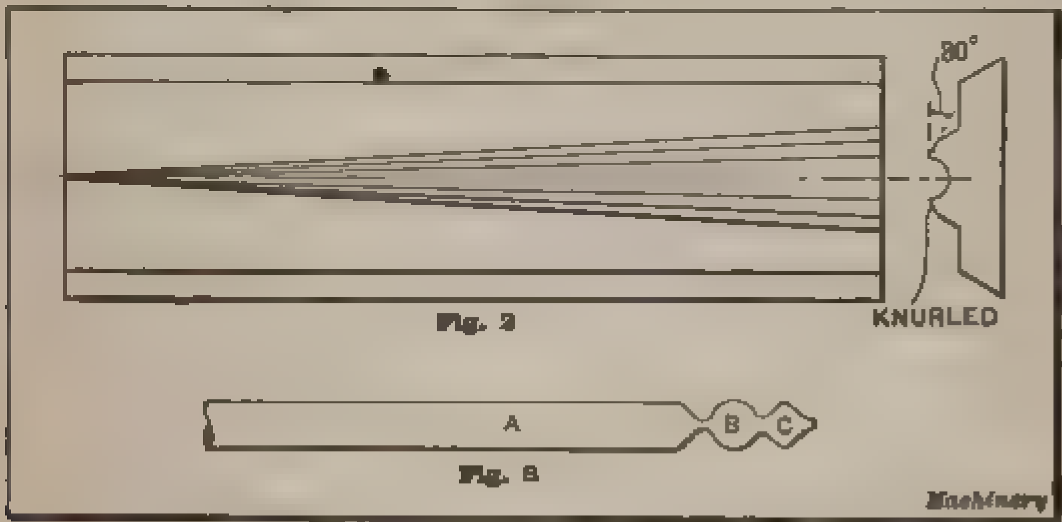

Fig. 2. Die for 3/8-inch Ball, used on Machine shown in Fig. 1
Fig. 3. Ball and Scrap resulting from Rolling Balls

once in the writer's experience some spindles 12 inches long and 5/16 inch in diameter were rolled with pipes right through so that a string could be put through the center. For this and other reasons, although the Simonds machine was most interesting from a mechanical point of view, it had comparatively little value commercially.

Several other ball companies had no good blanking process, and, therefore, hired men who understood the rolling process from the Simonds Co. A number of machines were thus designed similar to the Simonds type. One of these had circular platens instead of straight ones, and was made with circular dies, one within the other. The die holders, of course, were running in opposite directions. This machine worked satisfactorily, but the dies were much more difficult to make on account of their circular shape, and also on account of the fact that the inner die was smaller than the outer. The company designing this machine did not have a good grinding process and the machine was, therefore, soon abandoned on account of discontinuing the manufacture of balls.

Another rolling machine constructed on the same principle was made with platens of circular form running horizontally instead of vertically. The dies were circular, but of the same diameter, and were placed on the platen near the outer periphery. There were four dies in all to take up the circumference. The platens were run in opposite directions to each other. This machine was very rapid in its action and continuous in its operation, as the dies always ran in one direction and did not have to reverse. Another rolling machine was made

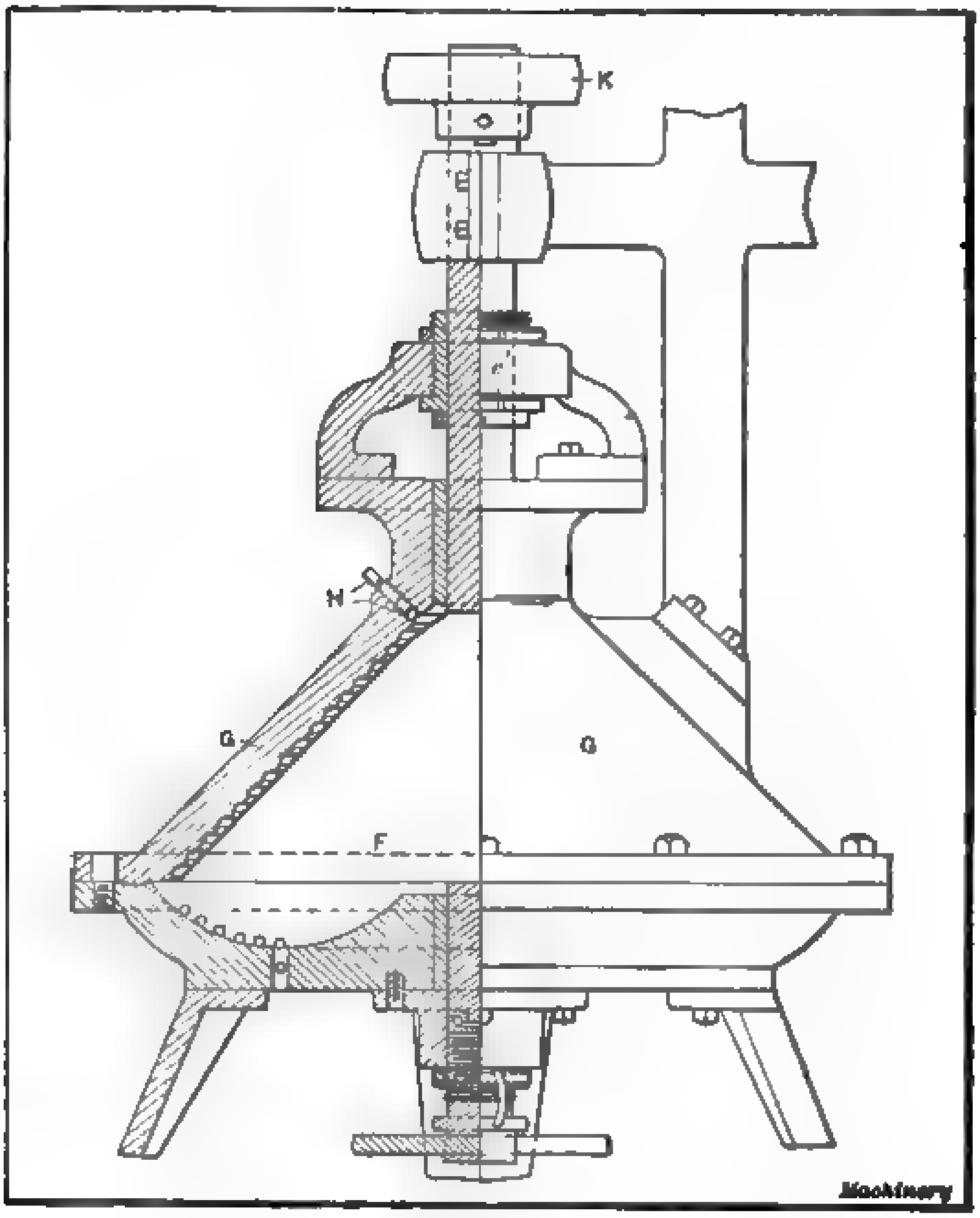

Fig. 4. The Christensen Ball Rolling Machine—U. S. Patent No. 632,330

with two small circular disks with the dies cut in the periphery. These disks were keyed to spindles which were geared together and were made to run in opposite directions. This machine worked satisfactorily on small balls, and is still used by some of the smaller ball manufacturing firms.

A number of machines have been designed from time to time for the making of ball blanks; some of these have been rather ingenious, although many of them have not been successful. In Fig. 4 is sh-

a machine invented by Mr M. F. Christensen, of Cleveland, O. The slugs or blanks H are fed in at the upper end of a cone-shaped device. The cone F revolves, being driven from pulley K. The inner face of the casing G is provided with a spiral groove from top to bottom, the section of the groove being more and more that of a complete circle as it approaches the bottom of the cone. The blank, as it runs around the cone, is supposed to be gradually rounded as it approaches the bottom. The machine, however, never proved successful for several reasons. The distance that the slugs or blanks had to travel proved a disadvantage, because if the slugs were heated, they became cold before they had passed through the device and would not compress, but were simply split open; if the slugs were not heated, the grain of the material was so distorted or crystallized that the balls could not be used. Again, if the slugs did not roll, but commenced to slide, causing clogging, the machine would have to be entirely dismantled in order to locate the trouble. Hence, after long and extensive experiments, it was abandoned.

Machines for Turning Ball Blanks

On account of the piping and burning of the steel and the difficulty of removing the teats from the balls, the manufacturers next took up the turning process for making ball blanks. The first successful machine invented was designed by the writer and is shown in Fig. 5. This machine is an automatic ball turning machine with a regular draw-back collet and automatic feed for the stock. The special feature of the machine is the manner of forming the ball. There is no turret slide or feed mechanism, but simply a solid tailstock with a heavy faceplate having a cam cut in the face, as indicated in the views at B and C. This cam is driven from cone pulley E through gears H, J and K. On the tailstock a plate with three jaws D, F and G is fastened, each of these jaws holding a forming tool and being provided with a roller which fits into the cam groove in the faceplate. When the machine is in operation, each jaw with its forming tool comes forward and does its share of the work (as indicated at L, M and N), and is then moved back to allow the next jaw to come into action. The last or third jaw cuts off the ball and rounds the end of the stock so that there will be a proper surface on which to start the cut for the next ball. Another form of turning machine was provided with a head similar to a regular plain automatic machine, having for toolholders rocker arms operated upon by a shaft at the rear of the machine. The shaft allows the arms to descend onto the stock to form the ball and then moves them back while the cutting-off tool performs its work.

The latest machine for ball turning is the Hoffmann machine shown in Fig. 6. This machine has two heads exactly alike, one at each end of the bed, these heads having regular automatic screw machine spindles. The slide in the middle of the bed is made very heavy because of being double and carrying two sets of forming tools. Four balls are formed at a time. The first ball from the stock end is about one finished, the second one, three-fourths finished, and the third one,

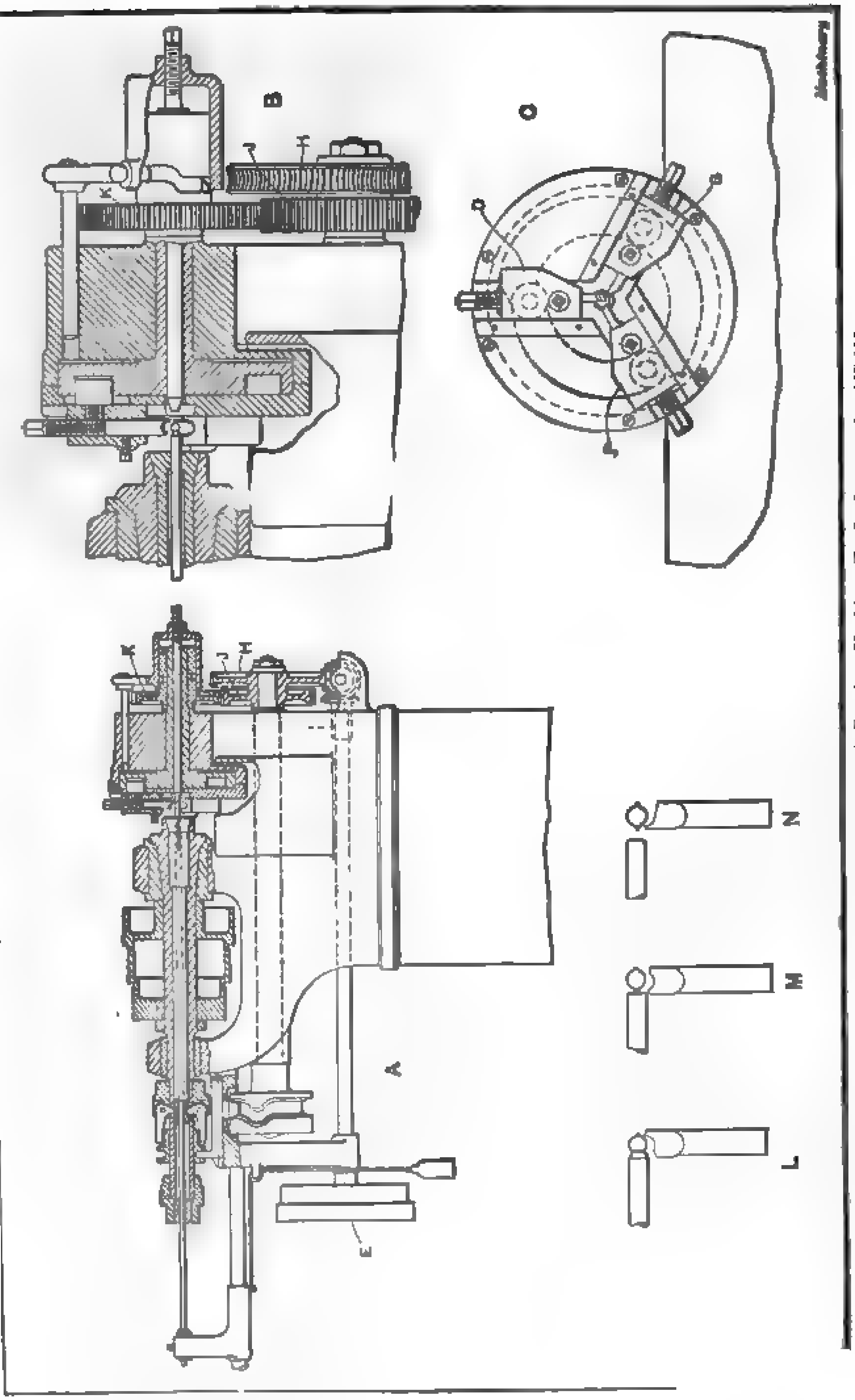

Fig. 4. The Grant Automatic Ball Turning Machine—U. S. Patent No. 517,984

completed, while the fourth ball is held in the second spindle, which is revolving at exactly the same speed as the first. This allows the forming tool to round the end of the ball so that it will be an accurate sphere. The ball is then fed on through the second spindle and drops into a pan. On account of forming four balls at a time, a roller rest

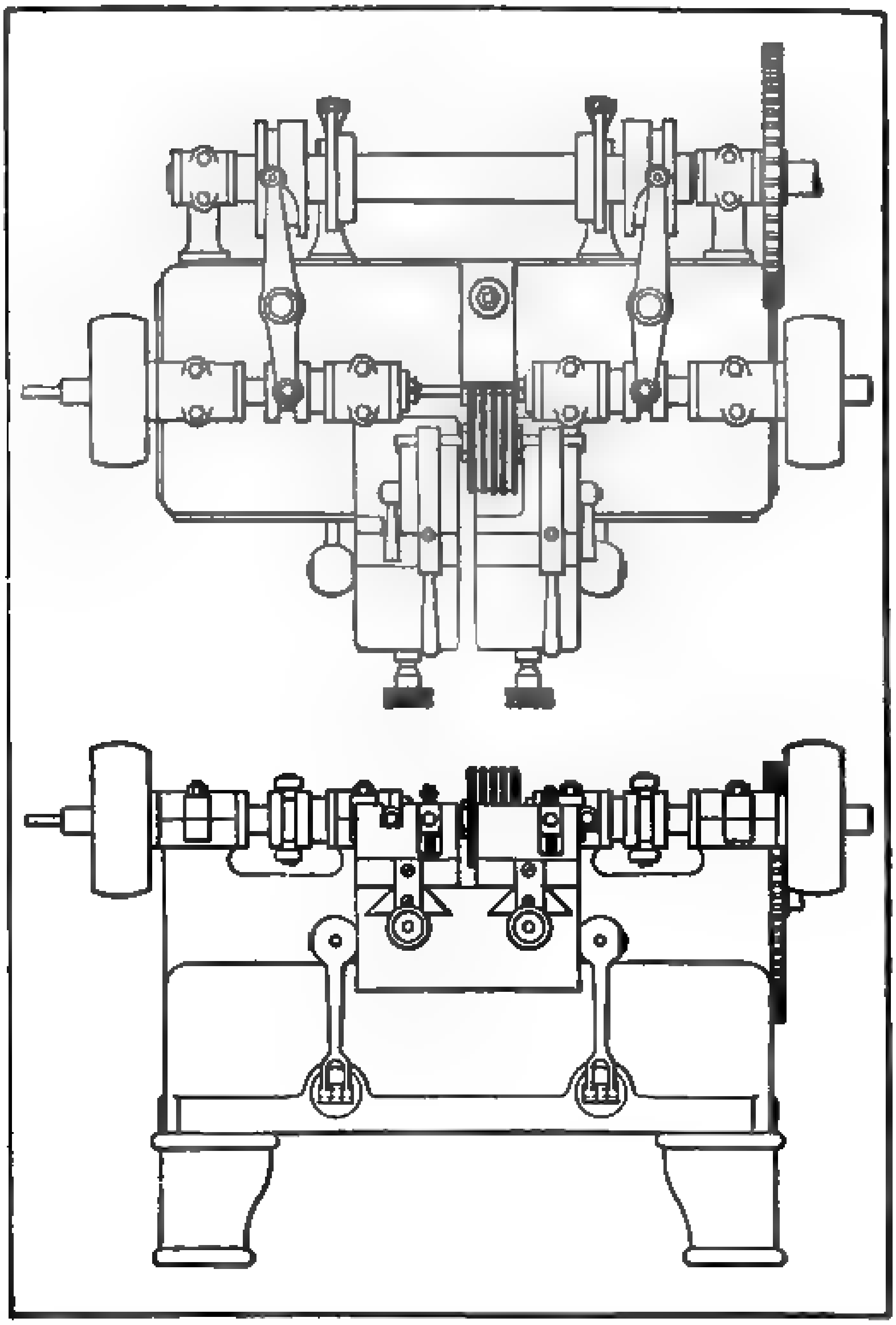

Fig. 6. The Hoffmann Ball Turning Machine—U. S. Patent No. 624,486

is used in the rear of the slide. This rest has two rollers made of hardened steel against which the stock revolves while the forming is being done. This allows the forming tool to form a perfect ball, as the stock cannot recede while the tools are at work. This is a feature of considerable value when balls are turned from tool-steel rods which it is impossible to fully anneal.

When turning balls by the method described, the stock wasted is greater than that which goes into the ball. The method is, therefore, used very little for balls over one-fourth inch in diameter, because the price of the steel becomes an important factor in the cost of manufacture when larger sizes are made. Another disadvantage is that balls cut from the bar are not as strong as when made by other methods. The direction of the grains or fibers of the steel wire is lengthwise of the bar; therefore, when the ball is formed, these fibers are cut and exposed at the surface, making a ball which is inferior in strength after hardening to balls made by other methods.

Pressing Balls

About fifteen or twenty years ago, when the bicycle business was booming, the Cleveland Machine Screw Co., which was at that time one of the largest of the firms in the country manufacturing balls, was unable to make enough blanks by the turning process, so it developed a process of pressing the ball blanks. In Fig. 7 is shown a regular wire straightener and cutting-off machine by which a coil of wire was straightened and then cut into short lengths called "slugs." This cutting-off must be very carefully done as otherwise the ball made from the slug will be of poor quality, because of the ends or ragged parts being pressed into the ball and forming a cold shut. This may fall out during the grinding or hardening operations, the ball then having a pitted appearance. The length of the slugs also must be exact, otherwise the blanks will be badly out of shape. If the slugs are not square on the ends when placed in the die, they will crowd to one side, a lopsided ball being the result.

In Fig. 8 is shown a regular No. 2 Ferracute press with an automatic attachment for pressing balls. This attachment is entirely automatic in its action, the slugs being fed down from the hopper and then conveyed by an arm to the die where the ball is pressed, after which the latter is ejected by the knock-out. At *A* is shown the hopper which holds the slugs, and at *G*, a fork which works the hopper up and down, keeping the slugs falling into the tube *B*. Fork *G* is operated through the lever *D* which is given a reciprocating motion by cam *E*. Lever *D* also moves a rack operating pinion *C*, which latter has an arm attached to it that carries the slug from the bottom of tube *B* to the dies in the press proper. The press is so timed that the slug is firmly held between the dies for a moment before the dies come together, thus giving the feeding arm time to pull away. While the pressing is being done, the arm receives another slug from tube *B*. This method of pressing is very cheap and very little material is wasted. On account of the press being of the regular open-front type, however, the blanks can be pressed only a small amount, because otherwise the machine will spring away from the work which is not heated. Hence when larger diameters are pressed, the balls are only approximately spherical, and a large quantity of stock is left for the dry grinders to remove. It has, therefore, not been found practicable to press balls by this method when they are larger than 3/8 inch in diameter.

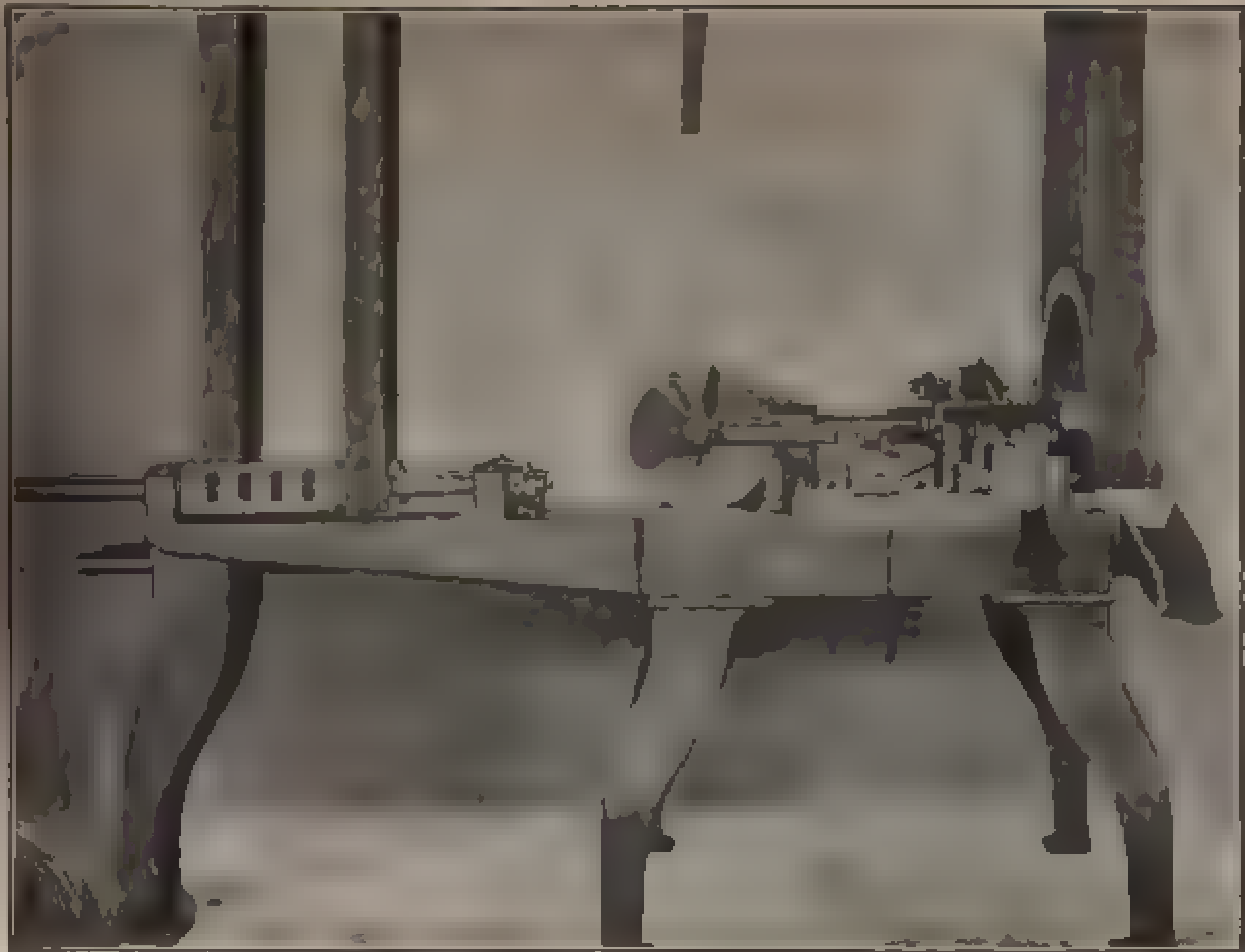

Fig. 7. Wire Straightening and Cutting-off Machine used for Cutting-off the Slugs for Pressing into Balls

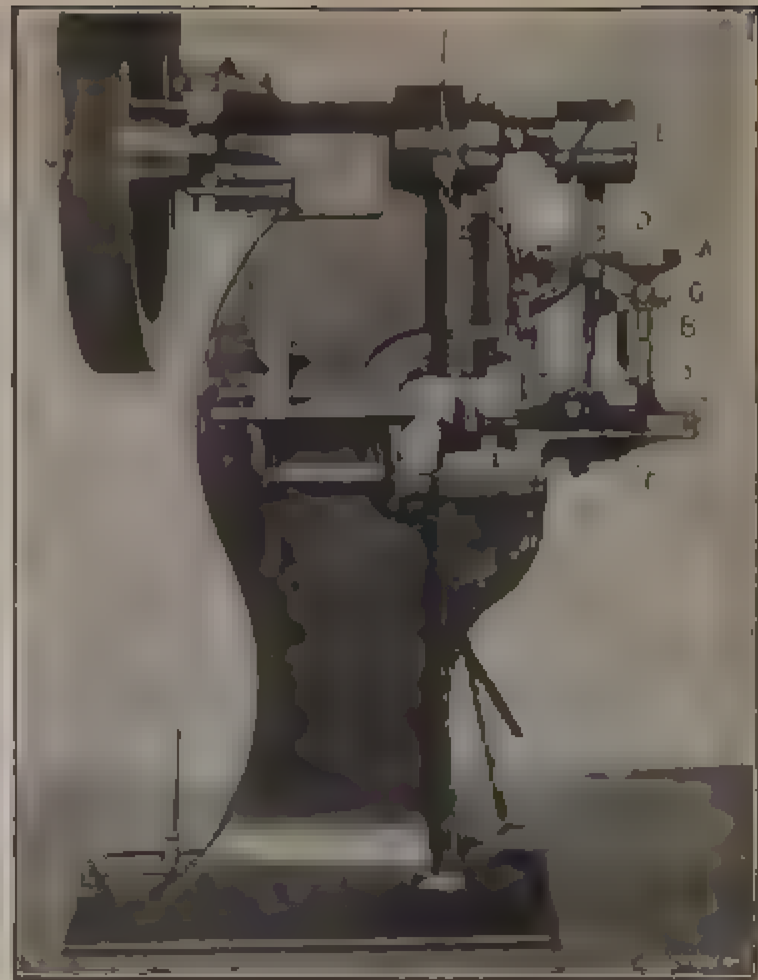

Fig. 8. Ferracute Press with Automatic Attachment for Pressing Balls

Fig. 9 shows a machine designed by Mr. M. Reid for cutting the slugs tapering at both ends, so that when pressing the ball no ragged edge can be pressed into it. The stock *A*, which comes in straight bars, is fed into the machine by gravity. Cutters *B* (shown also in Fig. 10), somewhat similar to pipe cutters, sever the stock and at the

same time taper the ends. The stock is then fed to dies *C* and *D* and the ball is formed as indicated by the various illustrations in Fig. 10. As this process is done with heated stock, a very good blank is produced. The sharp edges usually formed when cutting off the stock, are done away with by this method, and only the central part of the ball has to be pressed up, as the tapered ends are simply rounded.

The Manville Machine

The latest and best designed machine for the manufacture of small ball blanks is made by the E. J. Manville Machine Co., Waterbury,

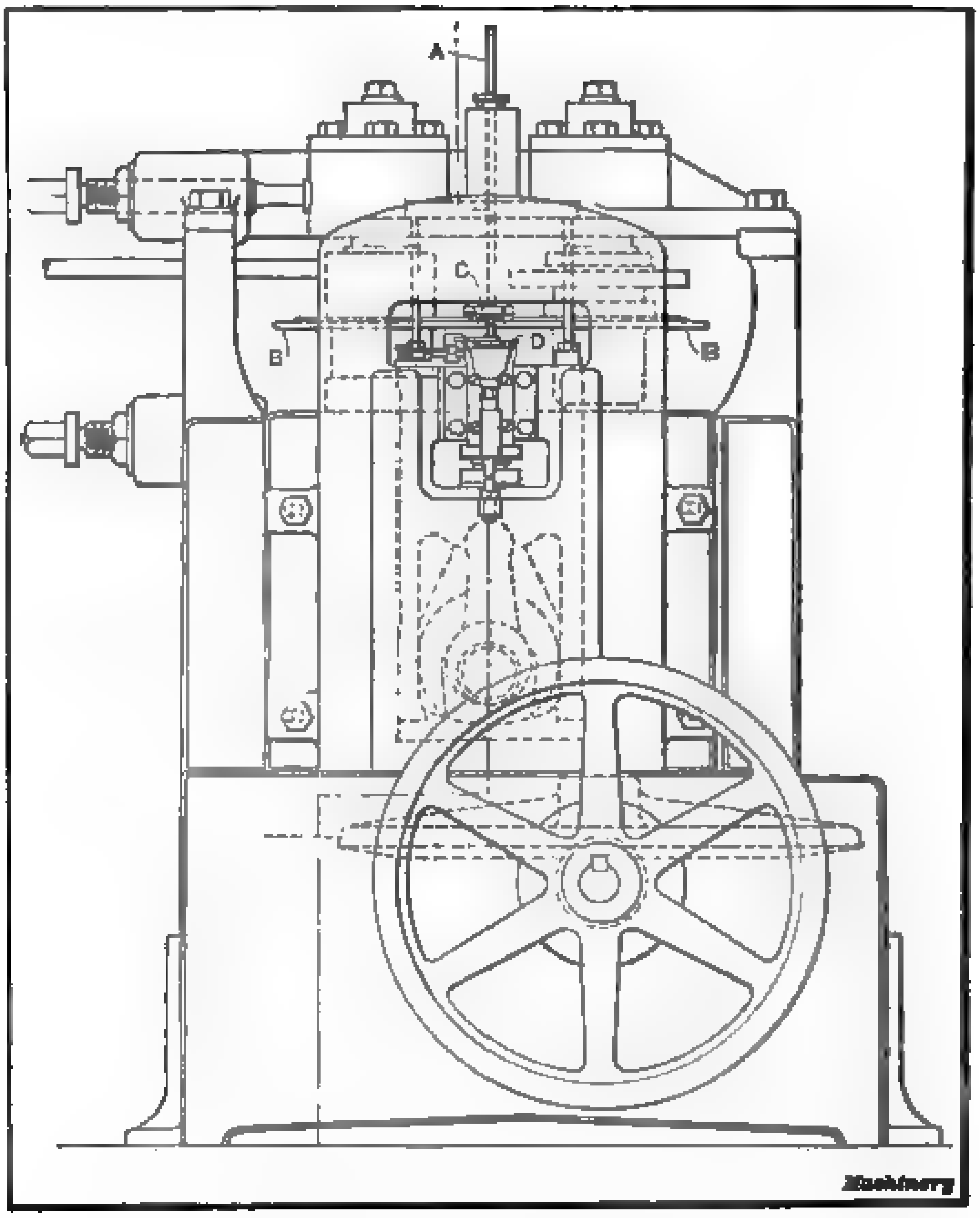

Fig. 9. The Reid Machine for Making Slugs with Tapered Ends and Pressing Balls—U. S. Patent No. 801,267

Conn. This machine has a coining-press type of frame, except that it is horizontal instead of vertical. All the work is done inside of the frame, so that a very accurate blank can be produced on account of the rigidity thus obtainable. Fig. 11 shows one of the smaller sizes

of these machines. This size is used for making balls up to ¼ inch in diameter. The stock which comes in coils is first passed through the straightening rolls *B* and then through tube *C* into the cutting-off die. Slide *E* has a cam which carries the cutting-off device or tool *F*. This cutting-off tool is flat and has spring fingers as indicated in Fig. 12. These fingers overlap the groove at the end of the cut-off tool.

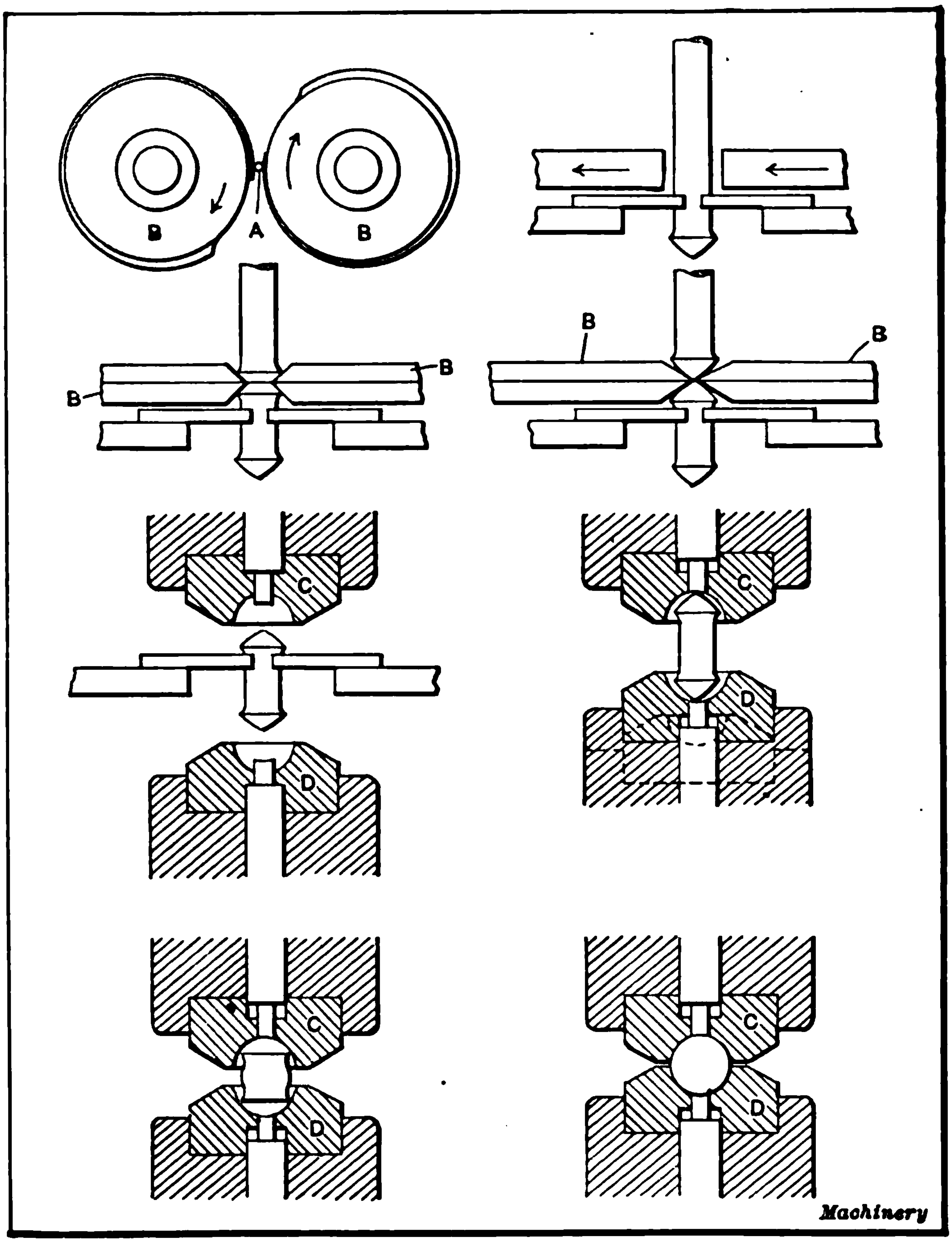

Fig. 10. Diagrammatical Views of the Various Stages of the Reid Process

After the stock has been cut off, these fingers hold the slug in position on the cut-off tool until the cam in slide *E* carries the tool with the slug over to the center of the dies. Die *G* is stationary and die *H* is mounted in movable slide *K*, which is carried forward by the eccentric on shaft *A*. As soon as the [illegible] between the two dies, the cut-off *F* moves [illegible] nd *H* to come together. The dies have [illegible] are counter-

bored from the back to within one-half inch from the impression in the die. (See Fig. 12.) In these counterbored holes, knock-out pins are placed which are worked by levers on the under side of the machine, so that as soon as the dies draw apart these pins will knock out the ball, no matter which die holds it.

The machine is very rapid in its operation and regular 3/16-inch

Fig. 11. The E. J. Manville Machine Co.'s Rivet Header arranged for Making Balls

balls can be made at the rate of 100,000 to 125,000 per day, according to the grade of the stock and the character of the annealing. One man can run three or four of these machines; hence the labor cost is so small as to be almost negligible. As there is no waste, this process, for smaller sizes of balls, must be deemed the best as well as the cheapest in ball manufacture at the present time. The following table gives sizes of stock used for making different sizes of balls:

Diameter of Ball, Inch	Diameter of Stock, Inch	Diameter of Ball, Inch	Diameter of Stock, Inch
1/8	0.095	9/32	0.200
5/32	0.120	5/16	0.225
3/16	0.145	3/8	0.265
7/32	0.165	7/16	0.312
1/4	0.180	1/2	0.355

Ball Forging

The best known method of making ball blanks from 3/8 inch to 2 inches in diameter is known as string forging. Fig. 13 shows a regular

upright helve hammer and a press, as well as a heating forge, the equipment being arranged for string forging. The bars from which the balls are forged are approximately 6 feet long. Twelve of these bars are put into the furnace at a time and are heated so that two sets of balls can be forged before putting the bar back into the furnace. By having a number of bars in the furnace at the same time, the heating can be done slowly and uniformly, and the bars are heated clear through to the center of the stock without burning or decarbonizing the surface. The forging of the balls requires some skill, as the bar must be turned and the hammer started at high speed, gradually slowing up as the blank begins to assume its proper shape. After being forged, the string of forged balls, indicated at *A* in Fig. 19, is placed in the trimming press where the whole row is forced through a series of holes, thus trimming

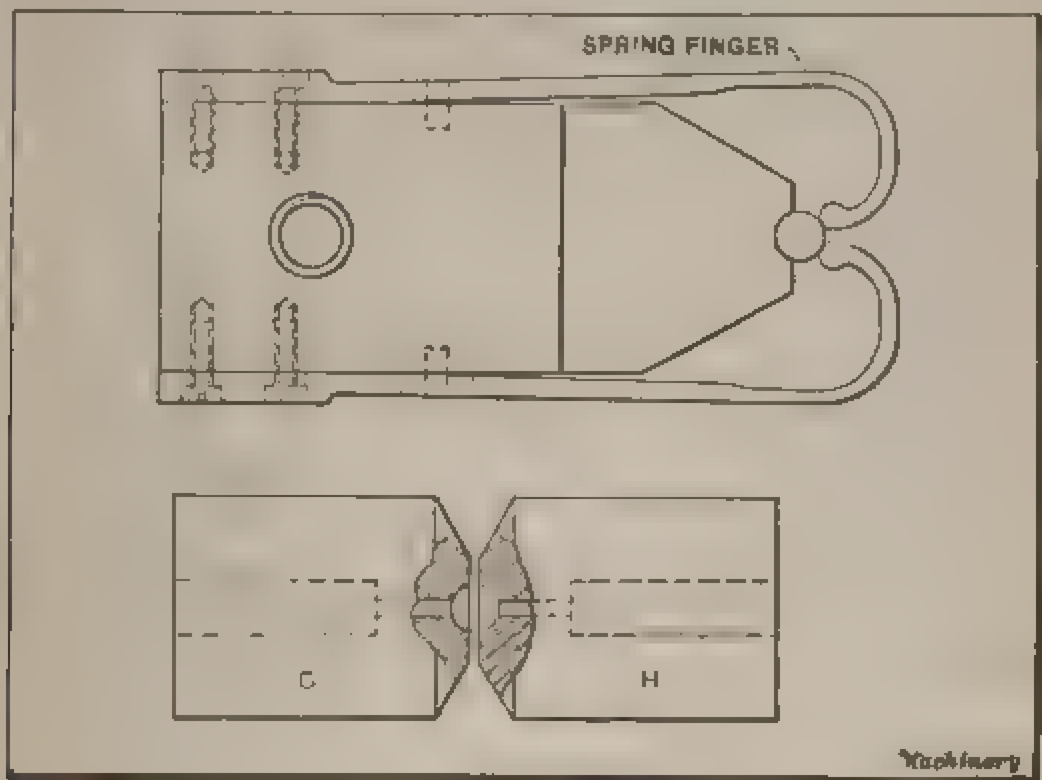

Fig. 12. Details of Cut-off Slide and Dies of Machine in Fig. 11

off the fins and separating the balls into individual blanks. The balls drop directly into a box under the press, as indicated.

Fig. 14 shows by a number of diagrammatical illustrations the manner in which the dies for string forging are made. At *A* is shown a section of a die with four impressions. The illustration also gives the notation of the die details necessary for use in connection with the following table. At *A*, for example, is indicated the diameter *D* of the cutter or cherry used in sinking the die, and also the depth *E* to which the cutter is sunk. In the view at *B* is given the distance *C* between the centers, so selected that when the proper size of stock is used, the die cavity will just be filled. It is also indicated here and at *F* that the die must be backed off or relieved on each side of the impressions, leaving only a small amount of land in the center to do the hammering. This backing off is done by moving the jig around on the milling machine or die sinking ma[illegible] sinking the cutter or cherry into the die about

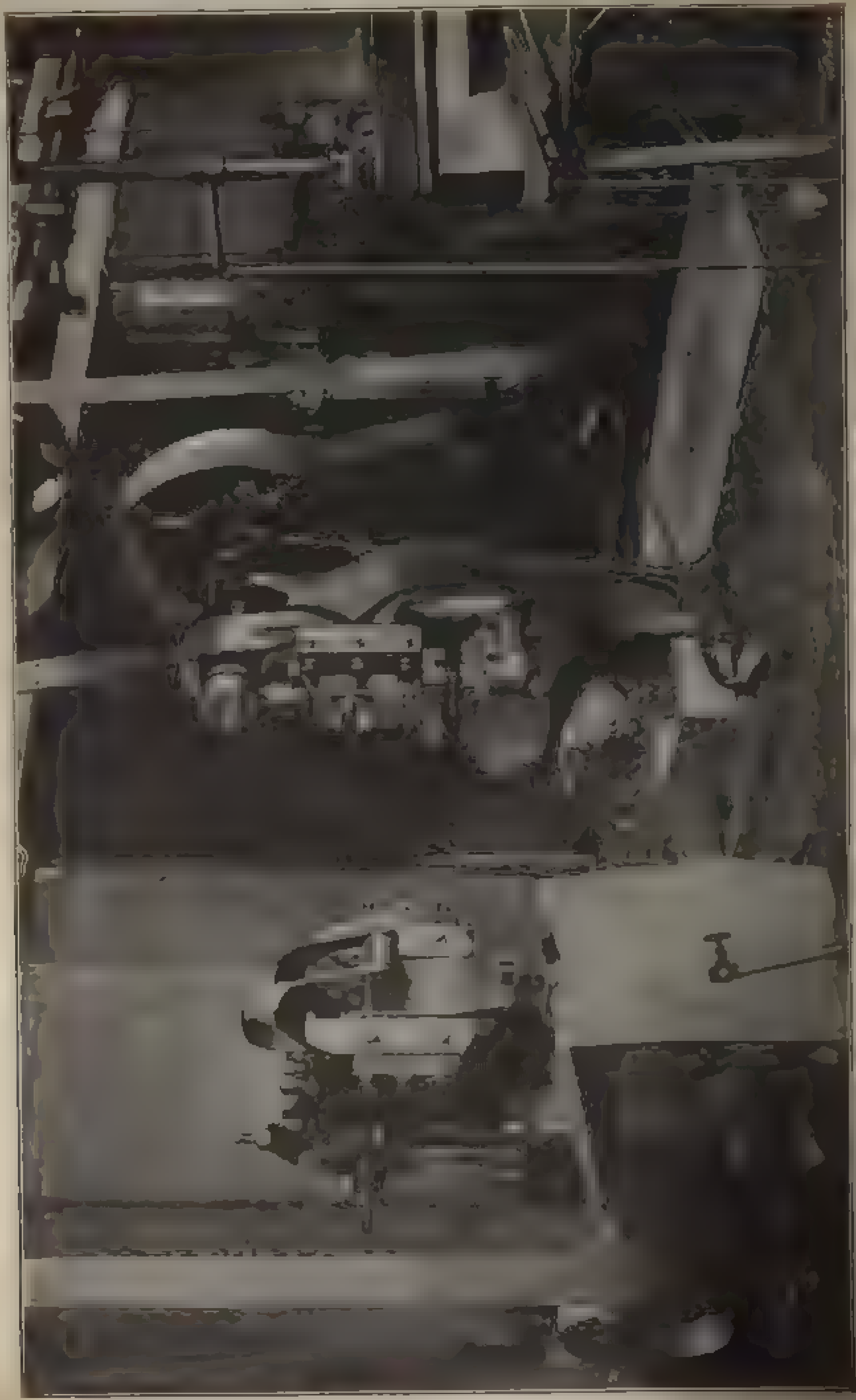

Fig. 18. Upright Helve Hammer and Press arranged for Steam Forging of Balls

1/16 inch, leaving the width of the center about one-third of the diameter of the ball. At *G* is shown the depth of the bridge, which is very important, as the neck formed by the bridge must hold the balls together during the forging and not draw the stock near the neck, so as to cause a pipe, which is very easily done. At *H* is shown the size of the stock

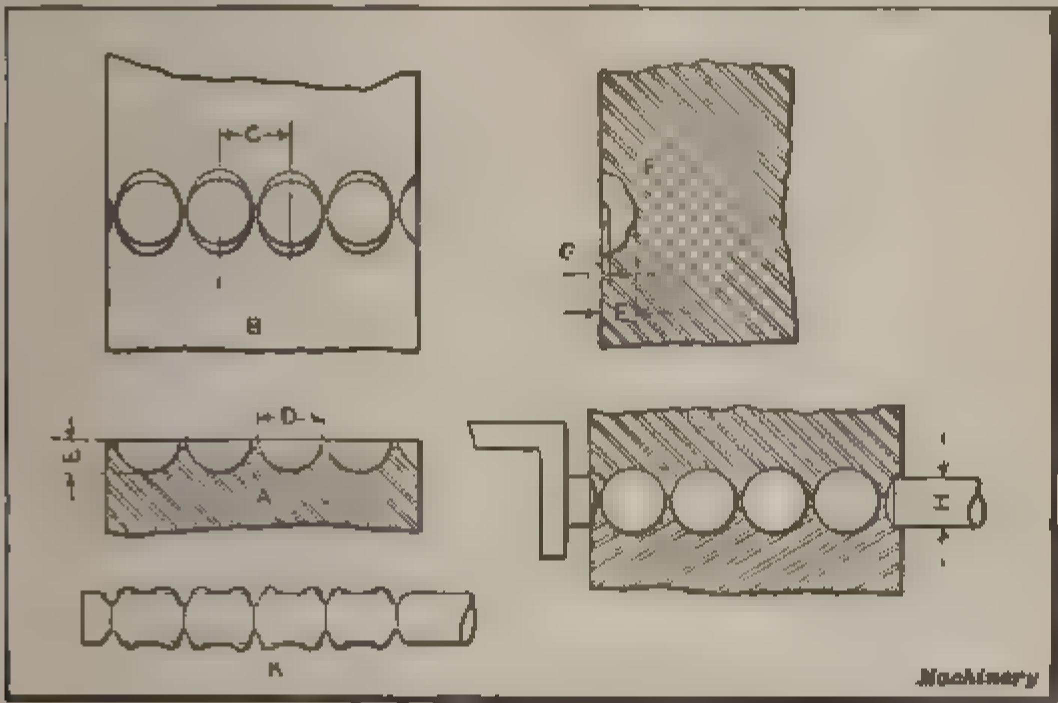

Fig. 14. Details of Dies for String Forging

which is always smaller than the diameter to be forged. The stock must be close to the required size; otherwise difficulties will be met with. If under size, the balls will not fill out; if too large, extra hammering

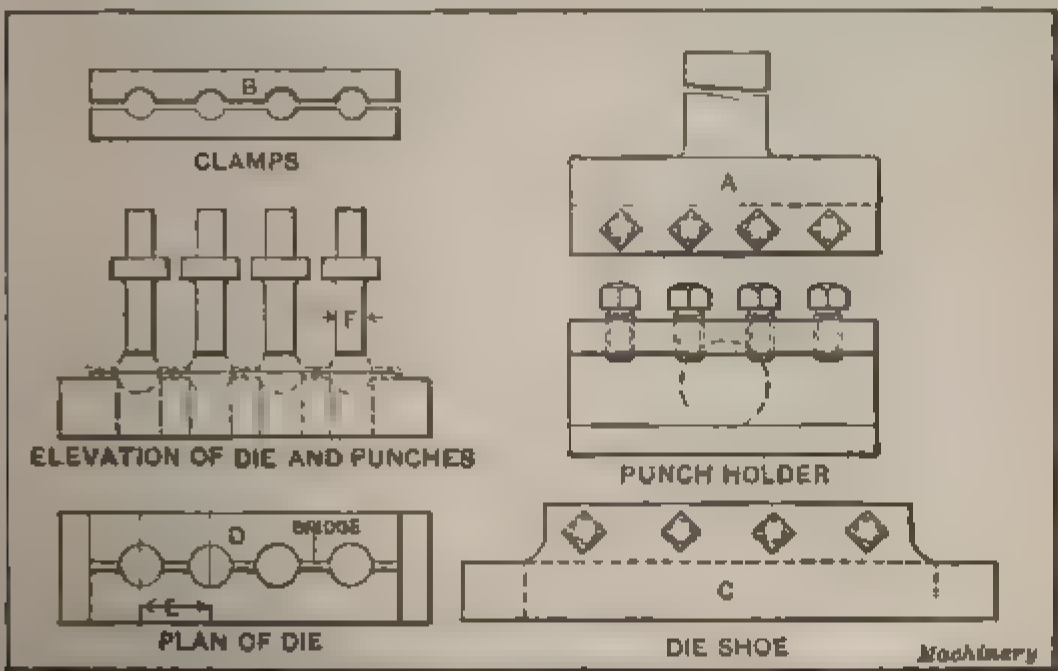

Fig. 15. Tools used for Trimming the Balls after Forging in a String

will be required, which causes the dies to soon wear out. In Fig. 14, four balls are shown forged at a time, but as this illustration is only diagr[illegible]atical, it is not implied that this is the correct number used ir[illegible]wing table gives the number of balls that would

be forged in a string for different sizes of balls, together with other dimensions required for the sinking of dies. At *K* is shown the stock after it has been slightly hammered to see if the dies are in perfect alignment. It is easily seen that when there are so many impressions in the dies, if the die warps in the hardening, the two dies will not match perfectly, and the balls at either end may be rather poor in quality. It is, therefore, very important to use a die steel that will hold its shape after hardening.

DATA FOR STRING FORGING OF BALLS
(See Fig. 14 for Notation.)

Size of Balls	Size of Stock, H	Diam. of Cutter, D	Distance Between Centers, C	Depth of Cavity, E	Depth of Bridge, G	No. of Balls
3/8	0.320	0.395	0.485	0.198	0.040	18
7/16	0.375	0.457	0.550	0.228	0.050	16
1/2	0.437	0.520	0.615	0.260	0.050	14
5/8	33/64	0.645	0.755	0.322	0.060	12
3/4	39/64	0.775	0.910	0.387	0.065	9
7/8	23/32	0.905	1.060	0.452	0.065	8
1	13/16	1.035	1.210	0.517	0.075	7

The necessary tools for the trimming of the balls are shown in Fig. 15. At *A* is shown the holder for the punches, the shank fitting into the head of the press. At *B* is shown a plate with holes drilled to the same diameter as the shanks of the punches. This plate is sawed in two, and after the punches are placed in the holes, it is clamped in holder *A* and held in place by four set-screws. The diameter *F* of the punches is about one-eighth inch less than the diameter of the balls. At *C* is shown a bolster fastened to the press and at *D* a plan of the die that is drilled with the same distance *E* between the centers of the holes as the distance between the forged balls. A groove is provided between the holes drilled in the bottom die *D* so that the necks between the balls will not touch the top of the die. Die *D* is placed in bolster *C* and lined up with the punches as in ordinary stamping processes.

The furnace used for heating the stock is of a special oil burning type. The burner is placed on the side of the furnace midway between the front and the rear. By having a special form of baffle plate directly in front of the flame, the latter is distributed throughout the furnace before it comes out at the front. An air pipe is passed under the opening through which the stock is put in to be heated. This pipe has a number of small holes drilled in the side facing the opening, and when air is forced through these holes, the heat is diverted upward and kept away from the operator.

Large balls, from 2½ inches up, are usually forged under a steam hammer. Stock of the proper diameter is first cut off to the required length and both ends are chamfered. The length of the stock is determined by the weight of the finished ball, an allowance for finishing being added. The blanks are placed in an oil furnace and allowed to heat slowly. Each time a blank is forged, a new one is put into its place in the furnace. The dies for this kind of forging are of an entirely different form from those used for string forgings. They

cupped out to the desired diameter, but are only sunk to a depth of one-quarter of the diameter of the ball to be forged, and are not backed off. When the blank is heated, the hammer man places it in the die, and the hammer is worked very slowly until the ball begins to take a spherical shape, at which time quicker and heavier blows are struck On account of the impressions in the dies being so shallow, the opera-

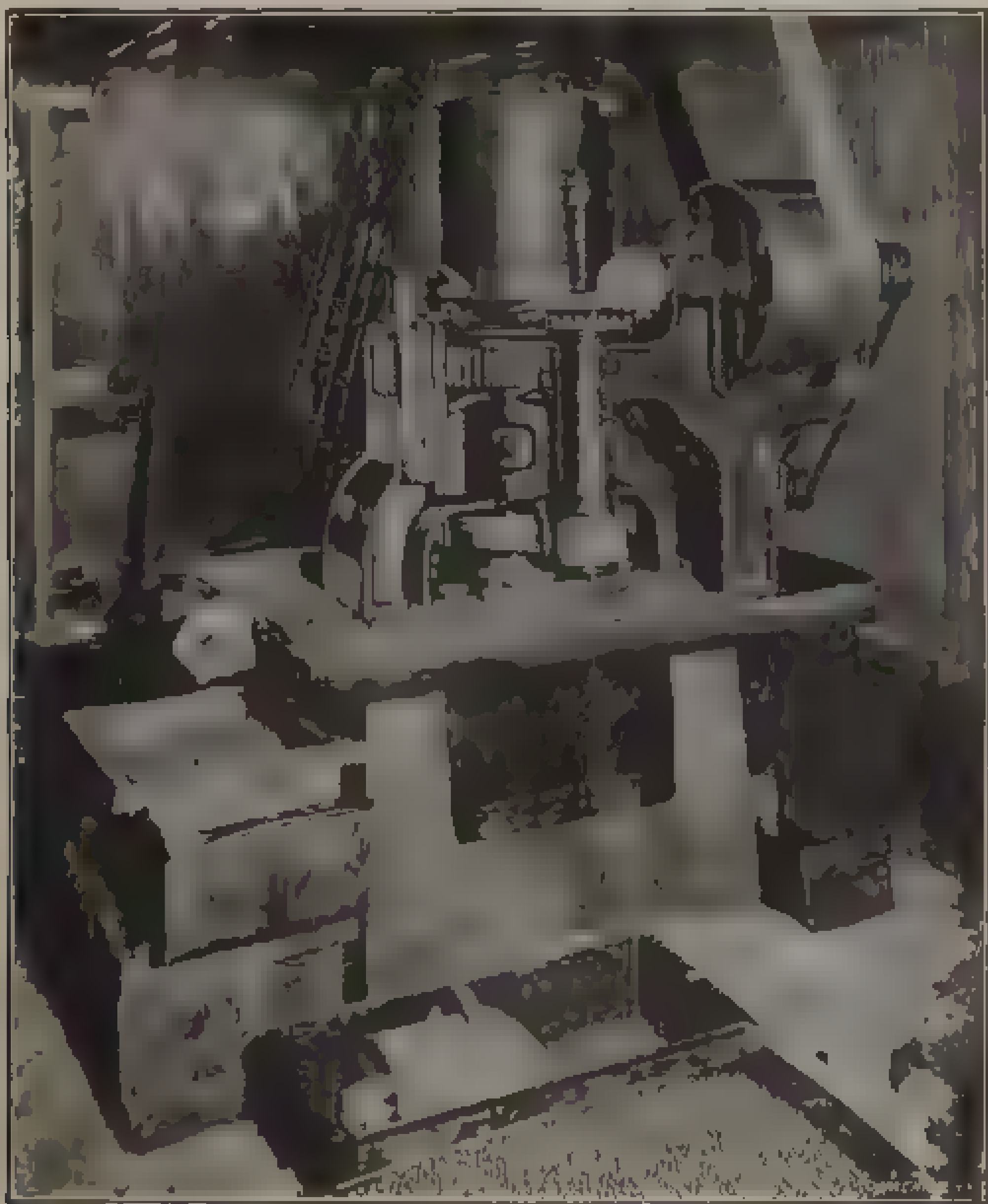

Fig. 16. "Flasher" or Rotary File used for Removing Fins from Forged Balls

tor has ample space to turn the ball in all directions, and can, therefore, produce an almost true sphere. Blanks 4 inches in diameter have been forged that have not been out of round over 0.005 or 0.006 inch.

The Flashing Process

The ball blanks as they come from the press or hammer are more or less out of shape a[illegible]d have a flash or fin or some other projection caused by the cutting-off or the wearing of the dies. These fins must be removed before the first grinding as they would otherwise mar the grinding rings. In Fig. 16 is shown what is known as a rotary file or flasher used for rem[illegible]hese fins. The balls are fed through the

spindle by gravity and discharged from the rotary filing plates by centrifugal action The head of the machine, which is run by a worm and worm-wheel, has a spindle to the end of which the rotary file is attached As the spindle is hollow, the balls can be fed through it to the center of the plate. The lower plate is solid, but is adjustable up and down, allowing for different sizes of balls and for wear. The balls as they pass from the spindle to the center of the plate, are filed by the upper plate revolving and forcing them over the lower, and they

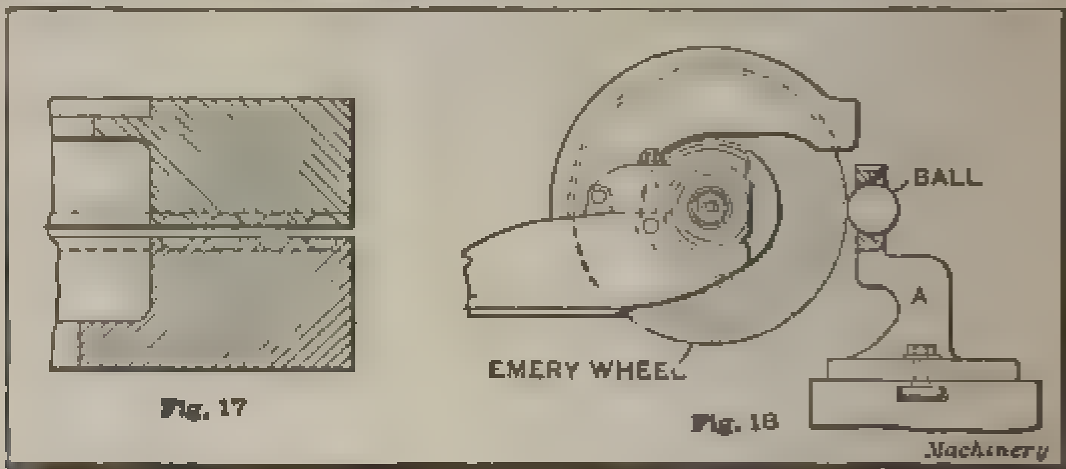

Fig. 17. Principle of Multiple Ring Grinder

Fig. 18. Method of Flashing Large Balls

fall out at the outer edge into a basket The operation is repeated after the lower plate has been adjusted. The plates are kept from clogging by a mixture of lard and kerosene oil, circulated by a pump from a tank below to a reservoir above

There is also another method of removing the flash or fin from the

Fig. 19. Sample of Balls made by Various Processes at Different Stages of Completion

balls, known as the multiple ring grinding process. Fig 17 shows a diagrammatical sketch of the principle of this method. Rings which are slightly grooved are placed on a heavy grinder similar to a drill press. The grooves are filled with balls and No. 36 emery or carborundum. The top ring is fastened to the spindle and allowed to revolve at a high speed while pressure is being applied In a short time the balls are removed and found to be comparatively smooth and ready for the first dry grinding.

The larger balls are ground separately in a very simple but effective way, as indicated in Fig. 18. An upright *A* is bolted to the table of a small emery wheel grinder This upright has a tapered hole through it into which the ball is pushed and adjusted so that the ball after the flash has been removed will barely touch the emery wheel. The operator, by means of a short pair of tongs, can turn the ball in all directions. As the ball cannot pass through the tapered hole in the upright more than a certain distance, flat spots cannot be ground, but the fin is simply removed and a smooth surface produced.

In Fig 19 are shown a number of samples of balls made by various processes and at different stages of completion. At *A* is shown a string of forged balls, and at *B* forged balls after trimming At *C* are shown a number of balls after being rough ground, at *D* the end of a bar operated upon in a Hoffmann ball turning machine, and at *E* a number of slugs and balls pressed from them.

Kind of Steel Used in Ball-making

The most important thing to be considered in the manufacture of balls is the quality of steel used One of the largest elevator companies in the United States tried 432 different samples of steel, obtained in this country and abroad. Balls from these samples were made and tested by being put into actual use. From these tests it was ascertained that the two grades of steel below (carbon and alloy) are best suited for making steel balls.

1—Carbon, 1 12, silicon, 0.015; phosphorus, 0.017; manganese, 0 19; sulphur, 0.019; chromium, 0.25 per cent.

2. Carbon, 0 95; silicon, 0 014, sulphur, 0 019, phosphorus, 0 018; manganese, 0 025; chromium, 1 25; tungsten, 0 25 per cent

It may be said without exaggeration that balls are used in nearly every kind of article that it is possible to name, provided it revolves. They are used in the cheapest kind of hardware and in the finest mechanisms and surveyors' instruments. Balls 1/16 inch in diameter are used in electric meters and typewriters. The number of balls being used for these purposes alone is from fifty to seventy-five millions per year. The largest balls made are about 6 inches in diameter.

CHAPTER II

ROUGH GRINDING, HARDENING AND FINISH GRINDING

In the previous chapter, the methods of making the blanks and preparing them for the dry grinding were explained In the present chapter the grinding and hardening operations will be dealt with The old English method of grinding the balls was mentioned in the previous chapter, the balls being ground between tw the upper one of which was revolved by hand T 'or balls

in the bicycle industry soon brought about improved methods for grinding, the first step being to fasten the top plate to the spindle of a drill press, while the bottom plate rested on the table of the machine In this way work was produced very much faster, but no better quality was obtained than formerly. About the time when the first steel balls were manufactured in this country, special grinding heads of a much more substantial character were devised. Fig 20 shows a row of oil grinders, such as were first made in this country. The head is made in the form of a goose neck, and has three bearings. The lower, or main, bearing has a quill the same as a drill press, with a rack cut in it. A lever with pinion teeth cut on the end meshes with this rack and provides the means for raising and lowering the head The spindle, which has a large faceplate fastened to the lower end, carries the

Fig 20 Battery of Early Type of Ball Grinding Machines

upper grinding ring, which is fastened to the faceplate by three screws. The main drive is through a set of bevel gears on the countershaft directly over the spindle of the machine A vertical shaft transmits the power from the countershaft to the spindle. As all the blanks at this time were either pressed or forged, instead of being turned, the amount of stock to be removed was considerably more than it is when turned ball blanks are used. For this reason the time required for grinding 1/4-inch balls was from one-half to three-quarters of an hour, and if the rings were badly worn the balls would come out of the grinder considerably out of true. It was, therefore, necessary to devise a better and quicker process—a rough grinder—for removing the surface of the balls. It is especially necessary to remove the surface to some depth when the balls are forged, as the outside is then apt to be decarbonized.

The Richardson Rough Grinder

The first rough grinder for balls was made by Mr. Henry Richardson, president of the Waltham Emery Wheel Co., Watham, Mass., in 1877. Mr. Richardson, in speaking of this machine, has mentioned a few interesting facts about his experiments along this line. He took a regular 16-inch bastard file and ground a 90-degree groove in the center, almost the entire length of the file. The groove was ground clear through the file so that it would allow a 5/16-inch ball to project through to such an extent that the ball could be ground by a wheel without the latter touching the file An emery wheel was then fastened to the faceplate of a lathe, and the file was clamped to the carriage in a vertical position A plate with an elongated slot, which could be moved up and down on the tailstock spindle, was then made The file with the balls was now placed against the balls. The lathe was then started The balls at once began to move in the V-groove in the file, and by moving the plate on the tailstock spindle up and down, the balls were turned in all directions, producing in a very short time a blank which was a comparatively true sphere, fairly accurate as to dimensions.

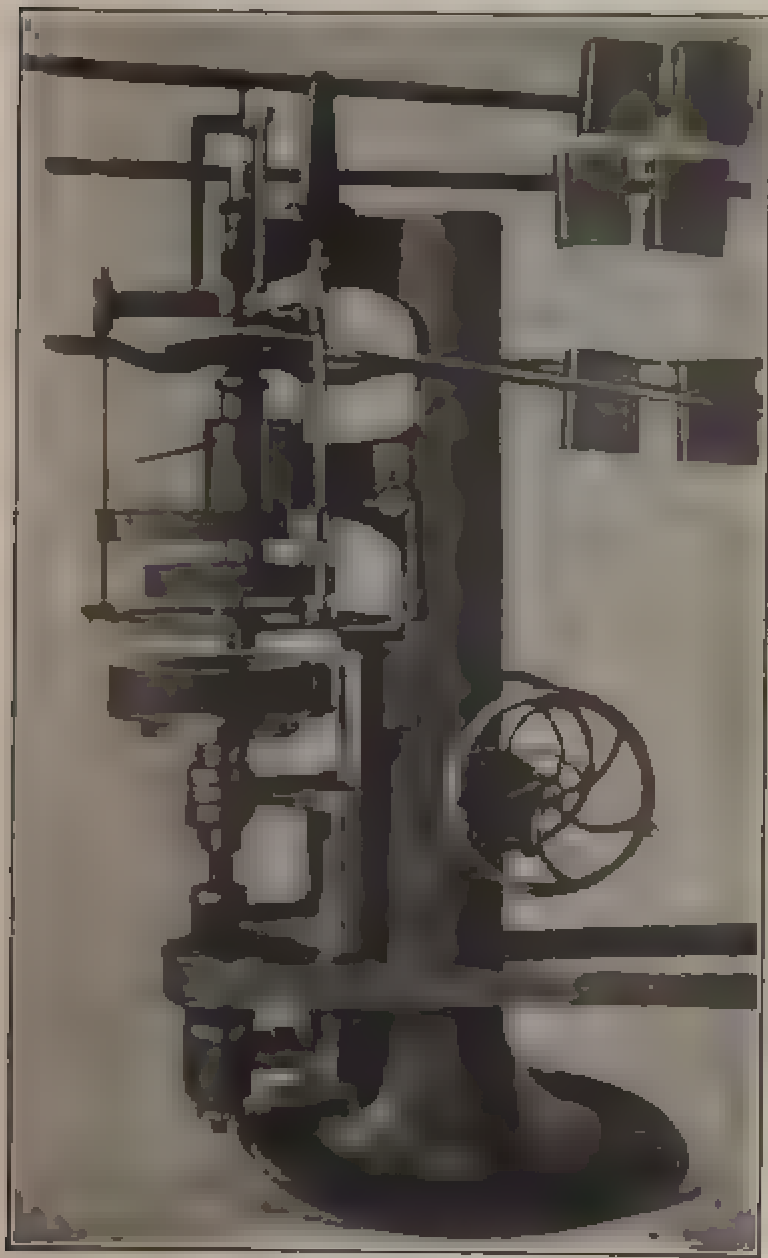

Fig. 21. Richardson's Ball Grinder

Mr Richardson then made a trial machine which worked very satisfactorily, but as a photograph of this machine was never made, no record of its appearance is preserved. In 1878 he went to England and sold the English patents to Mr. Wm. Bown. A sample machine, as shown in Fig 21, was made at this time The patent held by Mr Richardson did not, however, properly cover the invention, so that he was unable to get full returns for his efforts. The only claim of any importance which he held was as follows: a ring of balls in a V-groove,

revolved by a driving ring and exposed to an emery wheel. This claim was the direct result of his experiments, and by itself was very far-reaching. It gave the ball makers, who soon began to spring up all over the country, a great deal of trouble in their efforts to "go around" it.

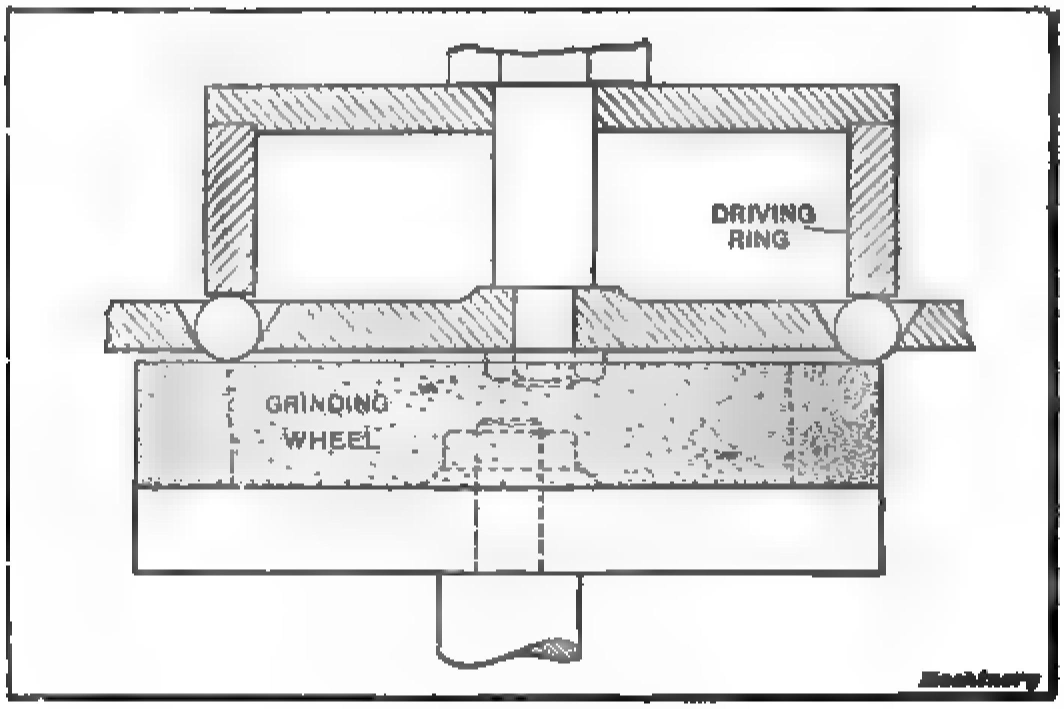

Fig. 22. Diagrammatical View of Principal Arrangement in the Richardson Ball Grinder

As shown in Fig. 21, the emery wheel is placed on the lower spindle which is mounted in the movable head; this head is operated by the handwheels at the rear of the machine. The emery wheel is eccentric

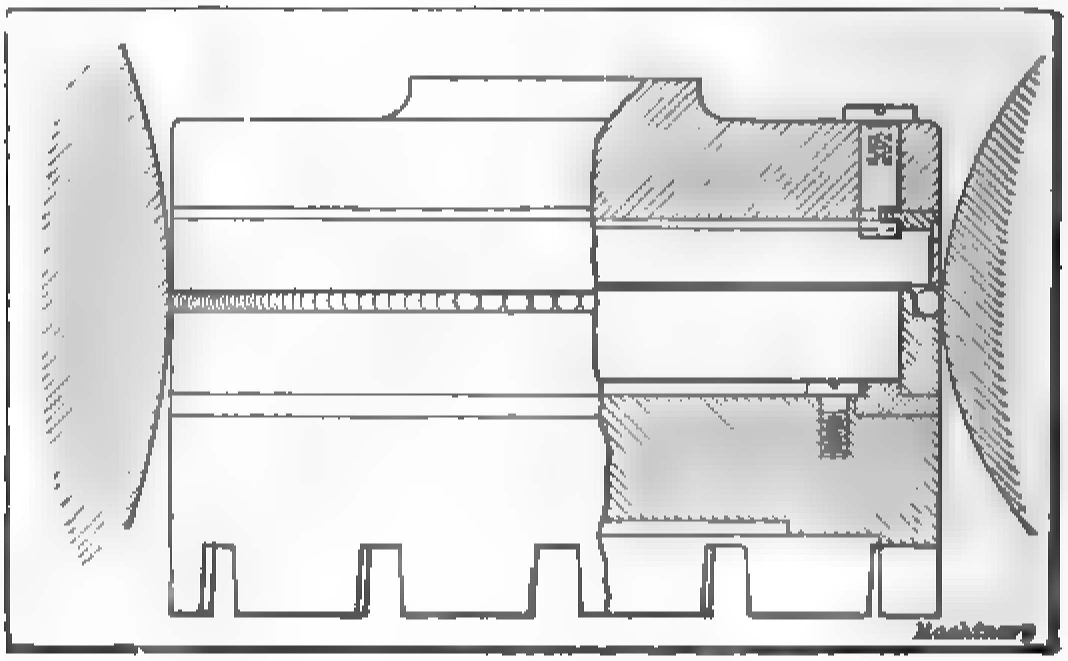

Fig. 23. Principle of the John J. Grant Rough Grinder—U. S. Patent No. 585,794

with the top ring, so that the whole surface of the wheel will successively come in contact with the balls. This keeps the wheel in perfect shape. The V-groove in which the balls rest is formed by two annular

rings or plates (see diagrammatical view in Fig 22), the outer one is held and adjusted by three long bolts (shown in Fig 21), while the inner plate is fastened to a rod which passes through the drive shaft to the top of the machine This inner plate is operated by the middle lever shown, so that the balls thus can be "dropped" when finished. The driving ring which revolves the balls is adjustable in an up and down direction by means of the lower lever, and is clamped in the proper position by the small lever on the main bearing This driving ring runs in the opposite direction to the emery wheel; the latter is run at a peripheral speed of approximately 5000 feet a minute.

On account of the fact that the outside of the balls run faster than the inside, as they are driven around by the drive ring, the balls assume a spiral motion, thereby exposing all sides to the emery wheel An approximately accurate sphere is thus produced.

The John J. Grant Rough Grinder

In 1888 when the Simonds Rolling Machine Co., of Fitchburg, Mass., was grinding balls by the old English method, it could only produce balls which were true within 0 003 inch. This accuracy was considered sufficient at that time Mr John J. Grant, who was at that time employed by this company, and who had improved the Simonds rolling machine, proceeded to devise a machine which made it possible to produce balls far superior to any ever made. The principle of his first machine, which was a rough grinder, is shown in Fig. 23. This machine produced excellent work, but was very slow in its operation, as the balls had to travel one-half of the circumference of the groove in the ring without coming in contact with the emery wheel On balls of smaller sizes, the upper or driving ring was so thin that it was possible to grind but a few balls before the emery wheel would wear it away. As shown in Fig. 23, the balls were held at the periphery of the stationary ring in a V-groove. The drive ring was extended over the balls far enough to drive them, and was driven by a pulley on the spindle which held the drive ring. The speed was not over 60 revolutions per minute. A saddle, which was stationary on the base of the machine, carried the emery wheel heads, each head having two wheels, so that the surface coming in contact with the ball would be as wide as possible. The driving pulley was placed between the emery wheels, all being driven from the same countershaft. The upper or drive ring could be raised by a lever at the top of the machine, and the lower ring could be revolved by throwing out a latch with a foot lever This allowed the machine to be loaded and unloaded very rapidly Notwithstanding the fact that this machine was very slow, as compared with the Richardson machine in which the emery wheel was on the balls at all times, it was successful, and it was possible for the Simonds company to produce a ball better than those produced by any other manufacturers, and the company soon controlled the ball trade.

In 1891, the Grant Anti-Friction Ball C[illegible] formed by Mr. J J Grant, and a great many experim[illegible] inding of balls without the V-path and drive rin[illegible] the experi-

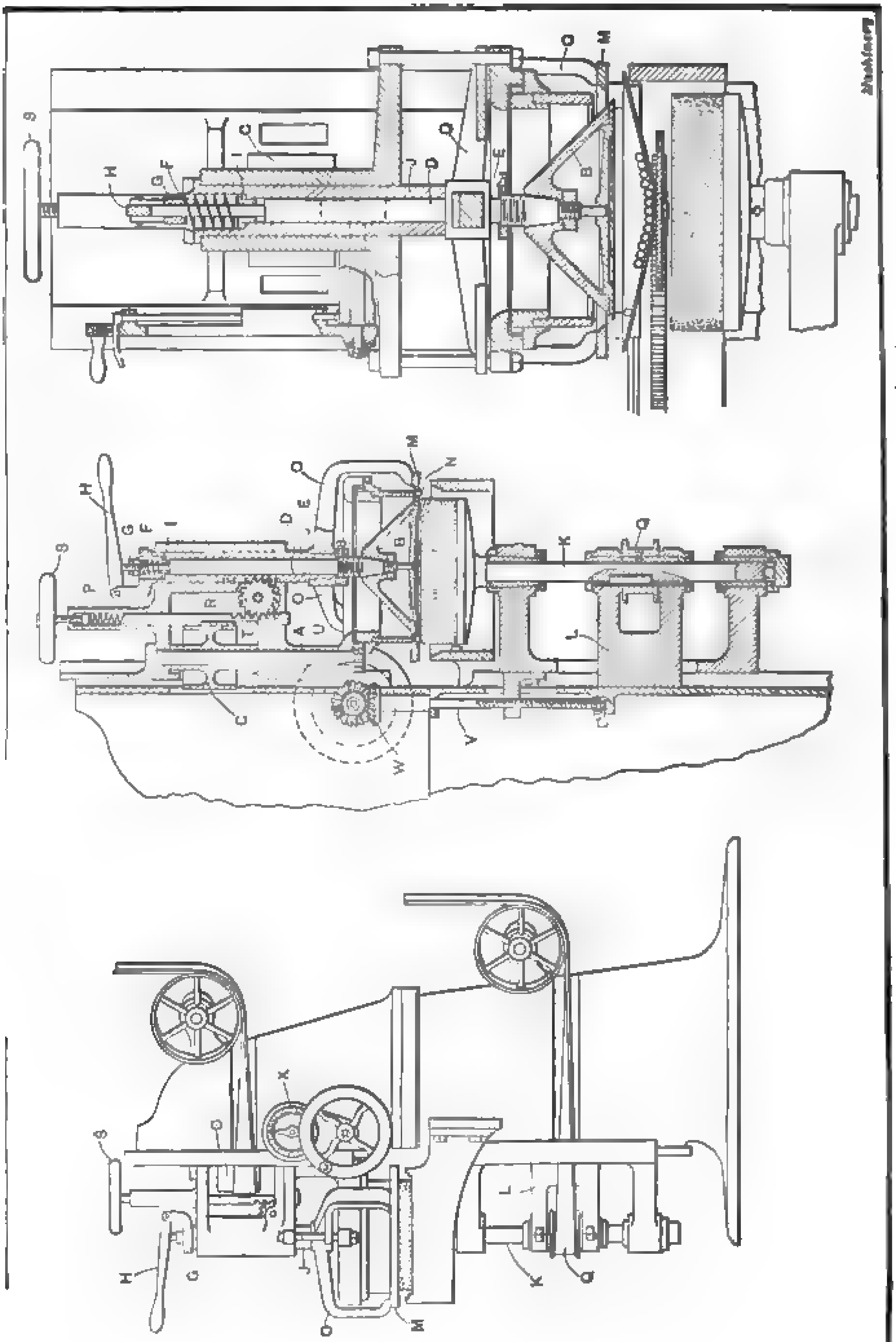

Fig. 24. Robert H. Grant Dry Grinding Machine—U. S. Patent No. 539,018

ments were not successful. It was, therefore, necessary to buy Mr. Richardson's patent, and around this was built the most successful dry grinder ever produced.

The Robert H. Grant Dry Grinder

In Fig. 24 are shown general and sectional views of the R. H. Grant grinding machine, as originally made. It will be seen that the Richardson path is used in a modified form. The drive ring is driven through a gear on the drive ring holder, this gear, in turn, being driven by pinion *U* which is fastened to the shaft *A*. This shaft carries pulley *C* at its upper end. The cone *B* has a plate with hardened segments screwed to its lower end which form the inner part of the race *N*. The cone is fastened to the shaft *D* which is adjustable by collar *E*. On the upper end of the shaft is a spring *F* which is compressed between the collar *I* and the adjustable sleeve *G*. By means of the lever *H*, the shaft *D* can be lowered, thereby allowing the balls to drop into a receptacle after being ground, as shown in the view to the right. On

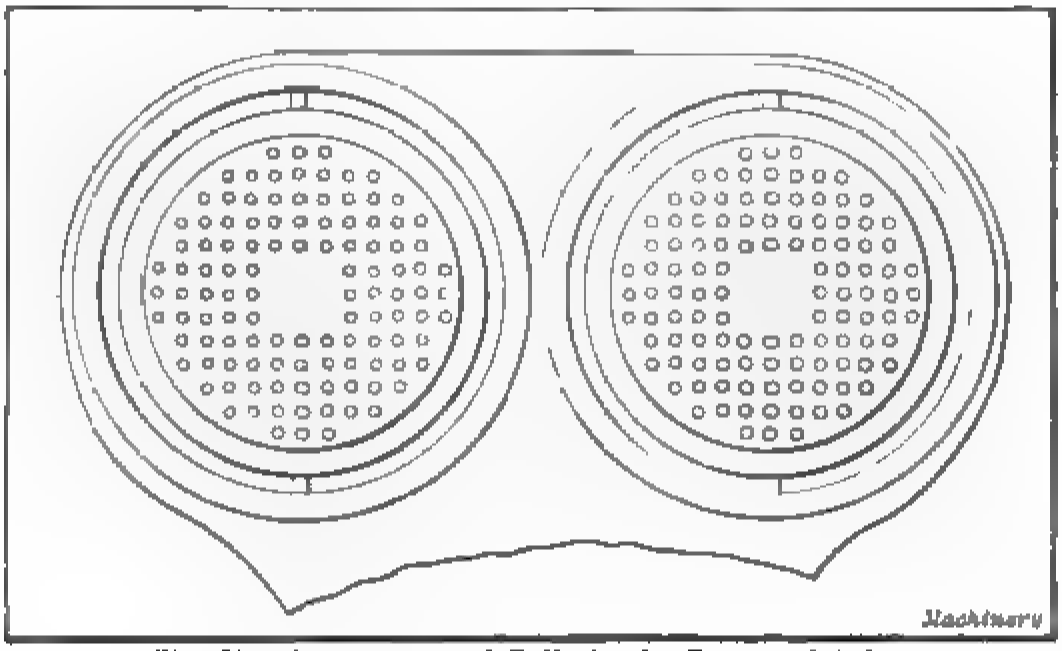

Fig. 25. Arrangement of Balls in the Putnam Grinder

the rear of the quill *J*, which carries the shaft *D*, is cut a rack in which pinion *R* works. The shaft *T* which operates pinion *R* is adjusted by the spring *P*, controlled by the handwheel *S*. On the lower part of the quill *J* is fastened the spider *O* which carries the ring *M*, to which are screwed the hardened segments forming the outer path.

It will be seen that when the rough forgings are placed in the V-path, the driving ring is stationary, but the inner ring can vibrate on account of the action of the spring *F*. The outer ring *M* is permitted to vibrate slightly through the means of the spider *O*, quill *J*, pinion *R* and spring *P*. In this way the rough forgings will be ground only on the high spots until the balls become round.

The loading and unloading is done without stopping. When the balls are finished, the emery wheel is lowered and a pan is pushed under the path of the balls. The handle *H* is pulled down, thus allowing the balls to fall into the pan. The spider *O* is then lowered by

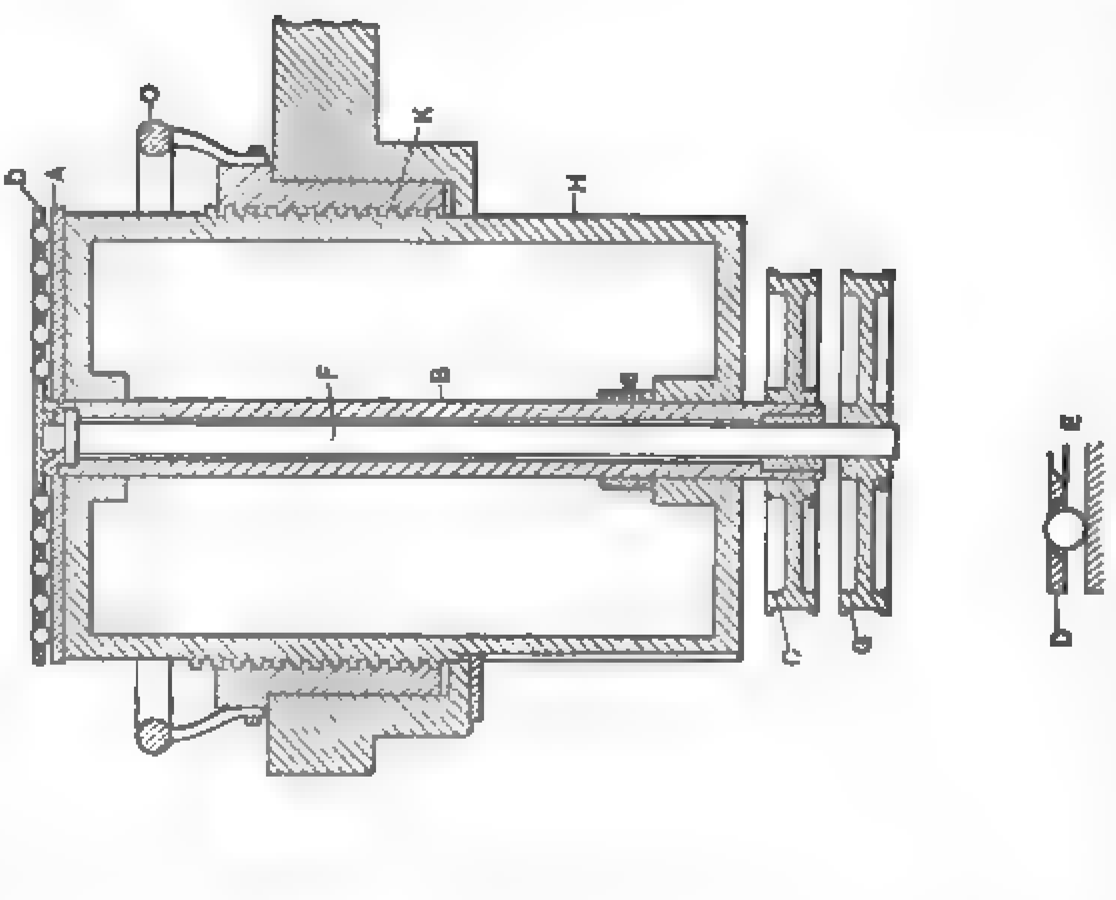

Fig. 57. Details of Principal Parts of the Putnam Grinding Machine

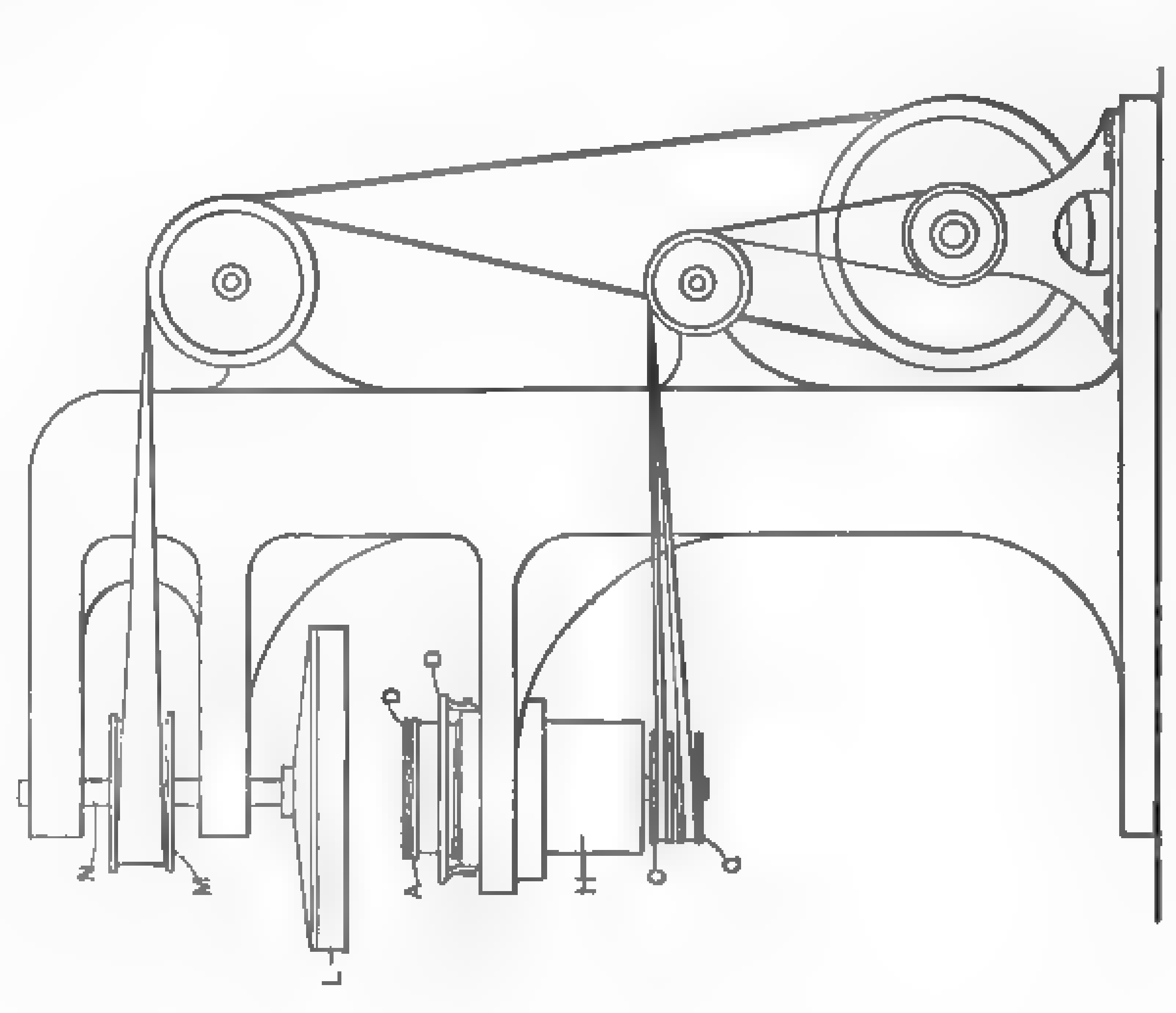

Fig. 56. The Putnam Dry Grinder—U. S. Patent No. [illegible]

means of the lever on the end of the shaft carrying pinion *R*. This allows the balls to be ground to be fed into the path *N*, and permits the grinding to commence without interruption.

The emery wheel, which is eccentric with the path of the balls, so as to allow the balls to successively cover the whole surface of the wheel, is carried by the lower head. The spindle *K* carries the pulley

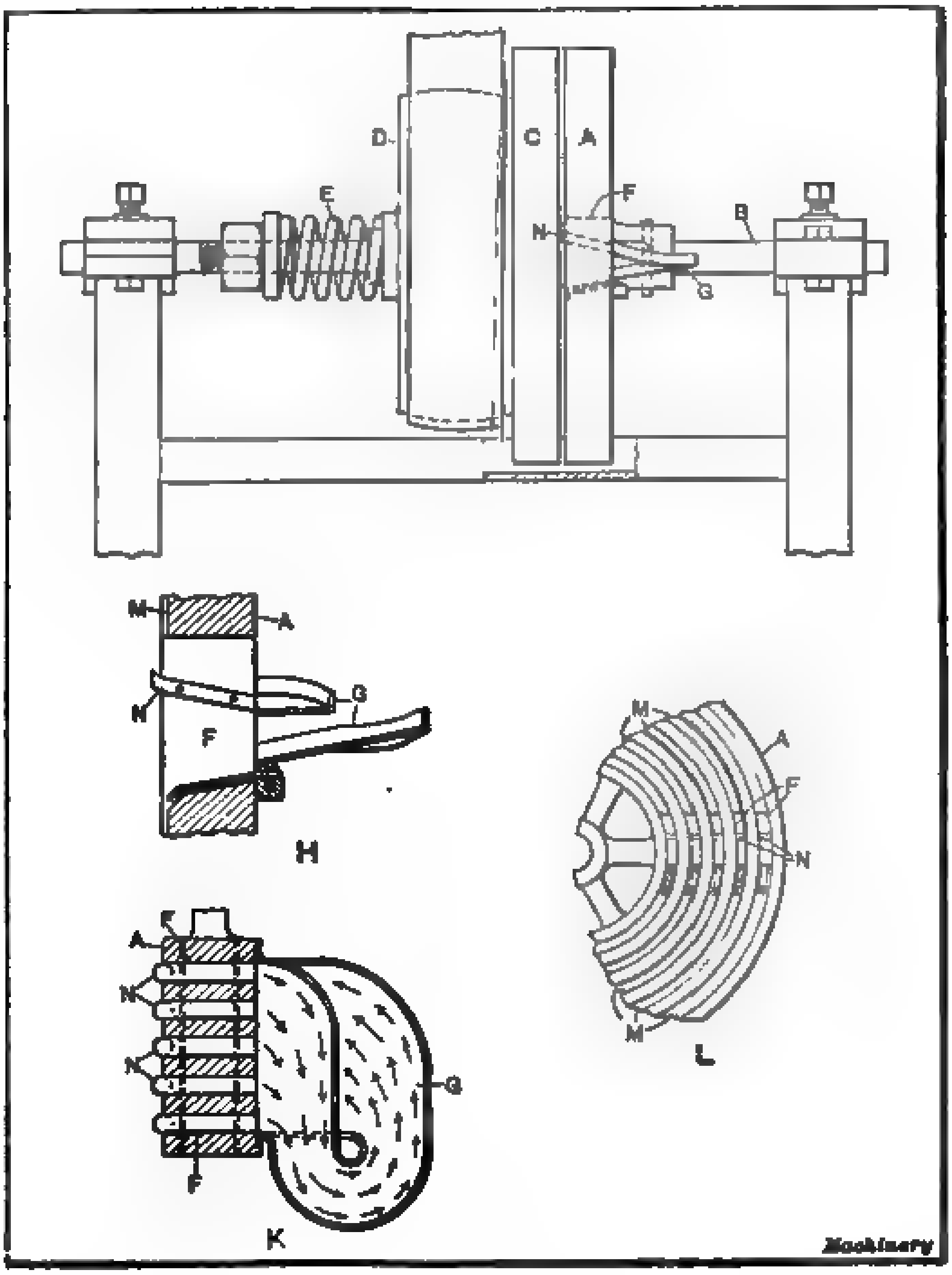

Fig. 26. The Hoffmann Ball Grinding Machine—U. S. Patent No. 803,164

Q which is driven by a belt running over idlers to the countershaft above. Head *L* is raised and lowered by the screw *V* and the bevel gears *W*. The indicator *X*, having a pointer as shown, is connected to this mechanism, and shows the operator how many thousandths inch more he must remove from the balls. With the introduction of this machine the cost of making balls was cut in two, and the quality obtained was far superior to anything which had so far been produced.

The Hawthorne Method of Rough Grinding

About the time when the writer had designed the machine just described, the Hawthorne Mfg. Co., of Bangor, Me., decided to enter into the manufacture of steel balls. This company originally manufactured boot calks and other lumbermen's supplies. Some articles were manufactured for this concern by the Simonds Rolling Machine Co., and representatives of the company frequently visited the Simonds plant. They observed the great number of balls that were beginning

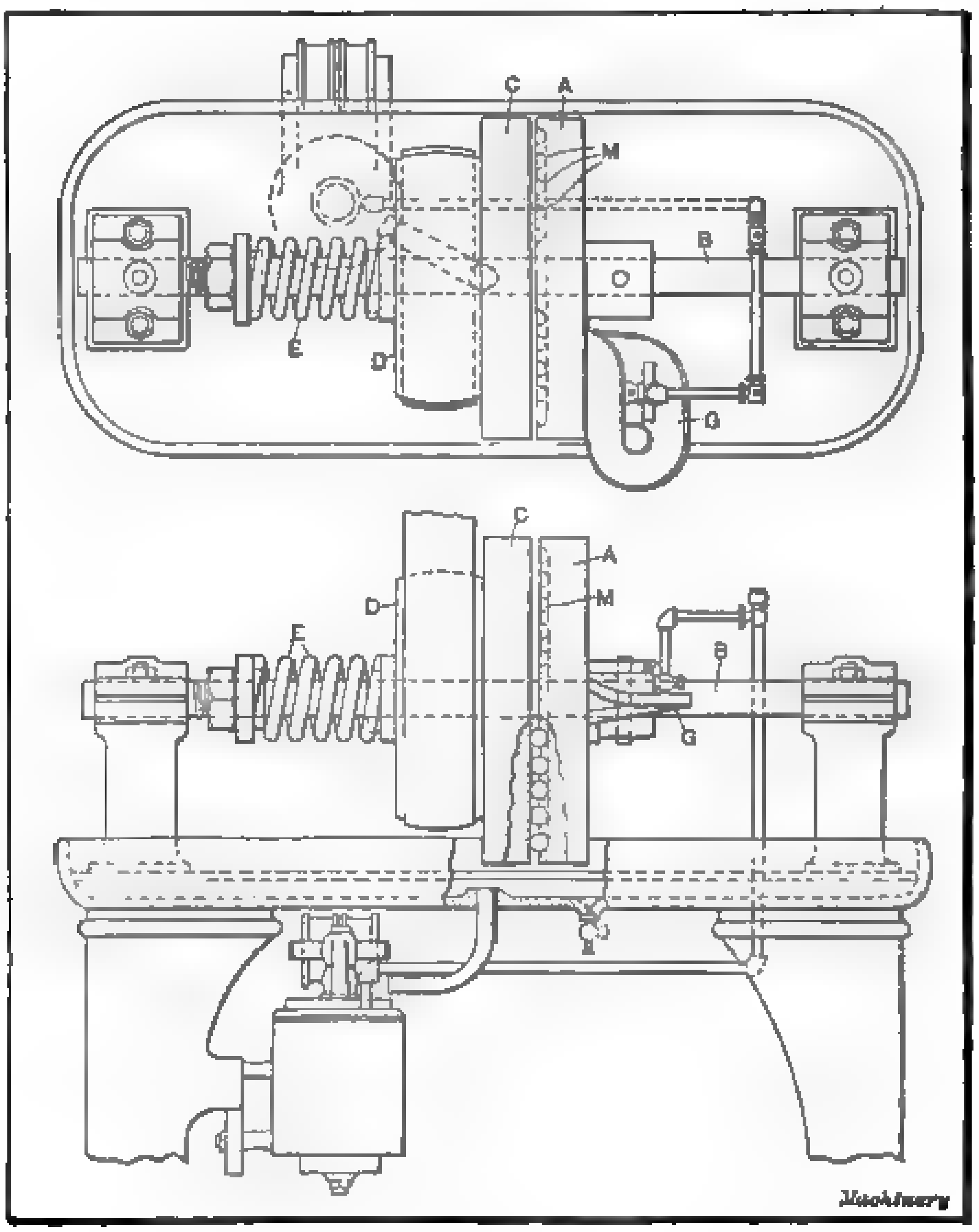

Fig. 29. Improved Hoffmann Ball Grinding Machine—U. S. Patent No. 868,926

to be used in this country, and hence concluded to enter into this field. The first grinder employed by this company made use of sand instead of emery. A bed of sand had been found in which the grit was so hard that it would cut the surface of a ball and last for a considerable length of time before being pulverized. The grinding was done in a closed path in which water and sand were used freely. The sand was fed from bins overhead, and washed out by water when pulverized.

This was a very cheap process, as far as the grinding material was concerned, but did not produce a perfectly spherical blank. The oil or finishing grinders had to be relied upon to round up the balls, and a great many seconds and thirds were produced. The process was applicable, however, to the small balls mostly used at that time, nearly all balls being employed in bicycles. For larger balls, such as are now used in automobiles and other machines of the present day, these machines would have been useless.

The Putnam Ball Grinding Machine

About 1899, Mr. H. M. Putnam, who for several years was connected with the Simonds Rolling Machine Co., started the Fitchburg Steel Ball Co., and invented a dry grinder, as shown in Figs. 25, 26 and 27. This machine, which had to be constructed without the Richardson path, was made in the following manner. The lower plate *A* which corresponds to the drive ring, was driven through the tube *B* which carries the pulley *C*. The plate *D* which is countersunk as indicated at *E*,

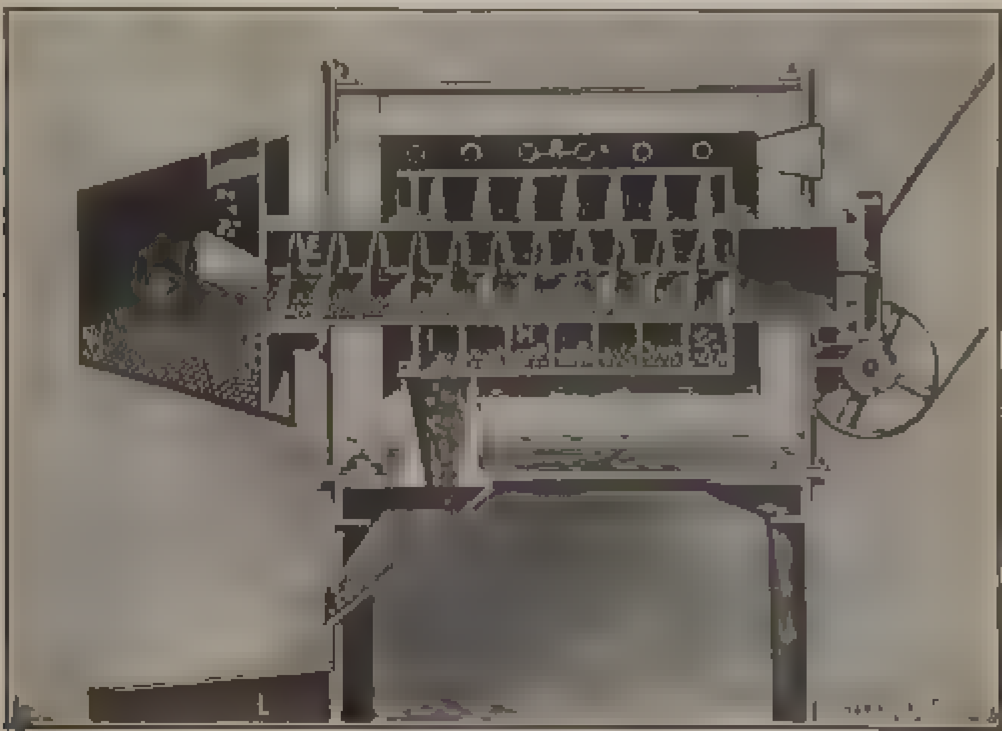

Fig. 30. Section of Ball Heating Furnace, made by the American Gas Furnace Co.

Fig. 27, (see also Fig. 25) is made from saw steel and hardened; it is then forced onto spindle *F* which carries pulley *G*. The cylinder *H* is adjustable by means of the screw thread *K*, and can thus, by means of handwheel *O*, be raised or lowered by the operator so that the balls will come in contact with the emery wheel *L*. This wheel is fastened to the upper spindle *N*, which is driven from pulley *M* by a belt passing over two idler pulleys to the countershaft on the floor, as shown. This machine is very simple, but it does not grind an accurate ball on account of the balls being at various distances from the center, thereby giving them different rates of speed. The outer balls are ground faster than those at the center, and thus balls of all kinds of diameters and degrees of accuracy are produced. The balls are not held firmly in the path as in the Richardson grinder, but are simply confined in the

countersunk holes so that they will not be thrown from the plate. This allows the ball to take its own course, and it becomes badly out of round during the grinding process. The writer is of the opinion that this machine might have been improved, but the company discontinued business soon after the machine was built.

The Chicago Steel Ball Co.'s Grinder

About the same time the Chicago Steel Ball Co., of Chicago, Ill., brought out a dry grinder which had several good features, and which was somewhat similar in operation to the well-known Hoffmann machine which will be described in detail in the following. The Chicago Steel Ball Co.'s machine had the emery wheel and the drive wheel placed in a vertical position. There were several concentric circular paths on the drive ring, and the balls were transferred from one into another,

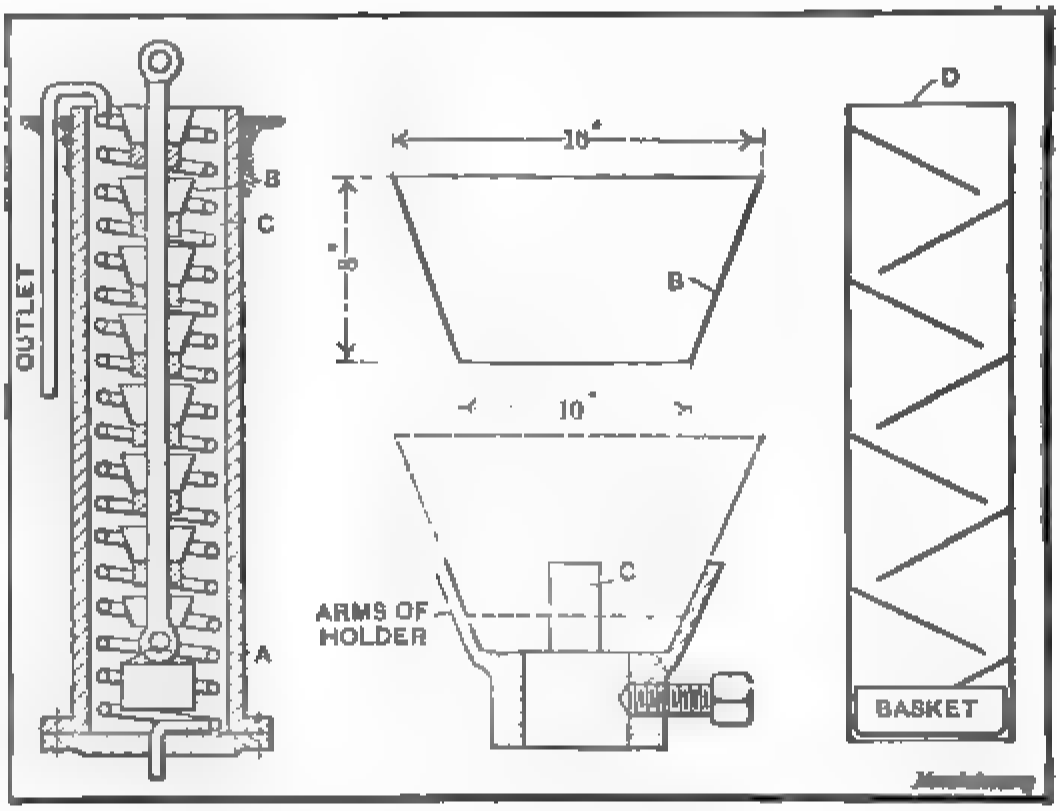

Fig. 31. Tanks used for Quenching Balls

thus giving the balls a different spiral motion on account of being at various distances from the center. This machine ground a very accurate ball, but on account of its poor construction and the poor method used for transferring the balls from one path to another, it was but little used, and, therefore, had no particular influence on ball manufacturing methods.

The Hoffmann Grinder

What may be considered as one of the best ball grinding machines constructed was invented in 1905 by Mr. E. G. Hoffmann, who was at that time connected with the Hoffmann Ball Co., in England. This machine required several years for its development, but when completed it produced a very accurate ball, and is greatly appreciated by ball manufacturers.

In the preceding chapter, the Hoffmann ball turning machine was

described. The blanks produced by this machine are accurate, and but little grinding is required on them. These balls, therefore, are especially suited for grinding in the Hoffmann grinder, as this machine is very slow, and cannot be used to advantage on pressed blanks or forgings, unless they have been previously rough ground by some other process. The machine is automatic, and requires little or no attention, except for gaging the balls at intervals during the grinding. The

Fig. 32. General View of the Grant Dry Grinding Machine, with Samples of Largest and Smallest Balls ground in it

machine requires from three to five hours for removing 0.001 inch on a ½-inch ball.

In Fig. 28, diagrammatical illustrations of the Hoffmann machine as originally designed, are shown. Pulley *D* is driven by a belt from the countershaft, and revolves upon a stationary shaft *B*. The pulley is fastened to the disk *C* which has a series of grooves in its face. Plate *A*, which also has a series of concentric grooves to correspond with those on disk *C*, is stationary and is fastened to shaft *B*. The balls are placed in the machine so as to fill all the concentric grooves, spring *E* forcing disk *C* against plate *A*, thus holding the balls in place. The machine is then started, and the balls, by means of the mixer and

interchanger shown in two views at H and K, are changed from one groove to another.

As indicated at H, K and L, slots F are cut through the stationary disk, a slot being directly opposite each of the grooves M. In each slot is placed a finger N which projects slightly beyond the bottom of the groove into the corresponding groove in the rotating disk C. The function of the finger is to stand in the path of the balls so as to positively dislodge each ball from the groove as it reaches the point where the finger is located. Each finger discharges the ball from the

Fig. 33. Special Grinding Machine used for Grinding the Segments for the Path of the Balls in the Machine shown in Fig. 32

corresponding groove upon a table G which affords a surface upon which the balls may roll, and which also directs the balls back toward the grooves below the fingers, the table being slightly inclined toward the lower portion of the slots F. It will be seen that this keeps the balls moving from one groove to another so as to place them at different distances from the center at each revolution of plate A. This results in the grinding of a very accurate ball.

The grinding is done with oil and emery introduced in the required quantities upon the table G, and fed into the machine by the balls. This machine was further improved by the introduction of an emery wheel in place of the grinding ring C. The improvement was very marked, as the grinder C, when made of cast iron, was apt to be spongy,

and softer in some spots than in others; it would, therefore, quickly wear out of shape The replacing of this disk by the emery wheel overcame these difficulties. Kerosene oil is used to keep the grooves clear of the loose particles of abrasive material, and prevents the balls from being badly scratched or cut. A very peculiar fact about this grinder is that the emery wheel is run at only 75 revolutions per minute, instead of at the peripheral speed of 5000 feet, generally required by emery wheel manufacturers.

Annealing and Hardening

After the balls have been rough ground so as to remove all scale and decarbonized surface resulting from the forging operation, they are

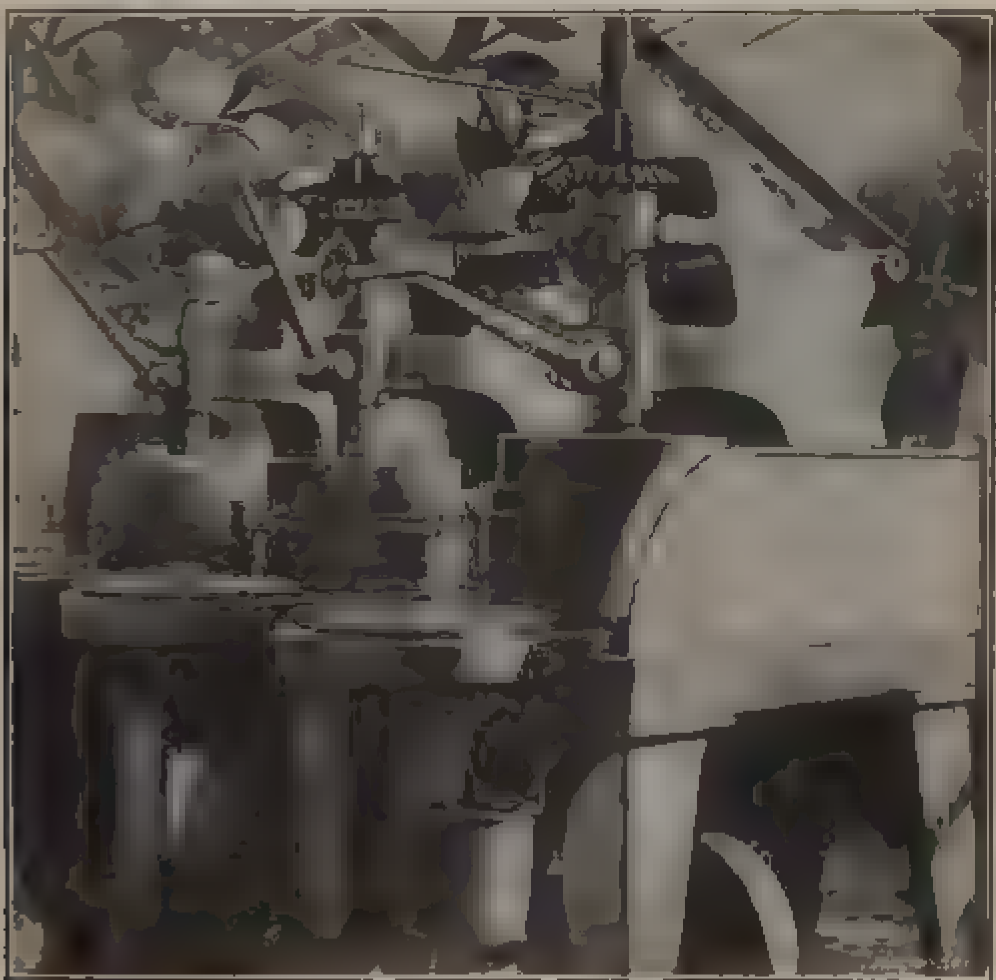

Fig. 34 The Oil Grinders

taken to the hardening room where they are first annealed This annealing removes any internal stresses caused by forging or other methods of blanking The process, as indicated in Fig. 30, is automatic The balls are fed into the hopper *B* which is revolved by a worm and worm wheel placed at the opposite end of the machine. From this hopper the balls are fed into the spiral *E* which they follow until they reach the opposite end, where they drop into the outer spiral *H*, which is revolved in the opposite direction. Finally the balls fall out of the cylinder at *I* into the funnel *K*. The machine is heated by gas with burners at *R*, thus preventing the heat from coming into direct contact with the balls and decarbonizing the surface.

After being annealed, the balls are put through the same machine to be heated for the hardening. They are heated to exactly 1275 degrees F., the temperature being determined by a pyrometer. The thermo-couple is placed near the point where the balls leave the cylinder.

The smaller balls are dropped into a reservoir of oil, while the larger ones are immersed in brine. The oil reservoir, shown at *A* in Fig. 31, consists of a length of 30-inch water pipe, one end being provided with a head strongly bolted to it so that it is water-tight. The pipe is sunk into the ground so that the top can receive the balls, as indicated at *L*, Fig. 30. Inside of this cast-iron pipe is placed a coil of 1¼ inch water pipe, in which cold water is circulated in order to keep the bath cool. A rod with a number of inverted galvanized iron cones *B*, adjustably fastened onto the rod by the holders *C*, is then placed in the bath. (Parts *B* and *C* are also shown in detail in Fig. 31.) When the balls drop into the bath in the pipe, they strike the side of the upper cone, which shoots them off at an angle until they strike the opposite side of the next cone; this reverses their direction of motion, so that they reach the basket at the bottom in a zigzag path, thoroughly cooled off. When the balls are thus cooled off, the rod with the basket at the lower end is pulled out, and the balls in the basket are allowed to drain, the oil draining back into the pipe.

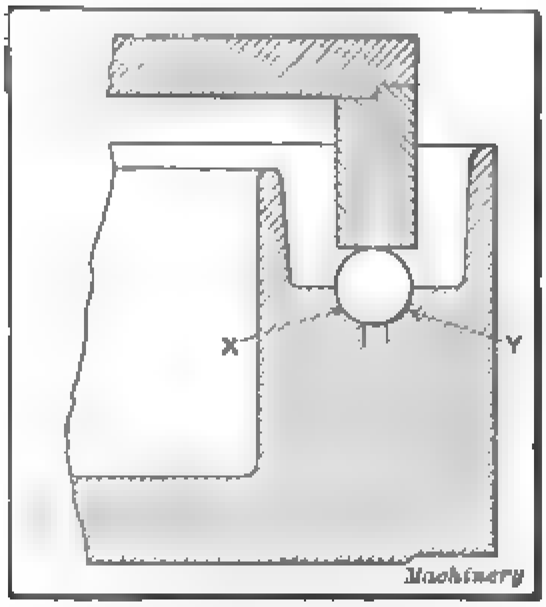

Fig. 35. Illustration of Principle of Action of Oil Grinders

The best oil for the hardening of balls is cotton-seed oil; while it is very expensive, it has sufficient body to cool the balls thoroughly, and it does not need to be replaced. It is only necessary to add to it, from time to time, due to the loss from evaporation.

The larger balls are hardened in brine. The machine shown in Fig. 30 is placed at the edge of a tank of the type shown at *D*, Fig. 31. This tank has a series of shutters made in the from of steps overlapping each other as indicated. These steps force the balls to traverse in a zigzag path through the brine in the tank for a considerable time before dropping into the basket at the bottom.

The largest balls are heated for hardening by being placed on the tiling of a regular casehardening furnace, similar to that made by the Brown & Sharpe Mfg. Co., and are allowed to heat slowly through to the center, the balls being revolved gradually. Two or more balls, according to size, are then placed in a wire basket and rapidly swung to and fro in the brine tank until thoroughly cooled off. All balls, as soon as they are taken from the hardening tanks are placed in a kettle of boiling soda, not only for the purpose of washing them, but also to

prevent the air from coming in contact with them at a time when they are extremely hard. The balls are then placed in the drawing kettles, which are filled with oil heated to 325 degrees F.

Finish Grinding

The balls are now ready to return to the finish dry grinding department, where the same machine as shown in Fig. 24 is used (except that a finer grade of emery wheel is employed) to reduce the balls to the proper size for the oil grinders. For this finish dry grinding the inner and outer segment are ground true, so that the path formed is a perfect track for the balls.

In Fig. 32, the improved Grant machine (Fig 24) is shown, with the two extremes in size of balls which this machine will grind. In Fig 33 is shown the special grinding machine which is used for grinding the segments that form the path for the balls. These special grinders are very simple in construction, the wheel head being solid and the spindle on which the segment plate is fastened being driven by a worm through a shaft from a pulley in the rear. The two adjustments up and down and in and out are operated by the shafts which project in the front. By this grinding, the segments are made absolutely true, and by grinding the drive ring by the emery wheel on the machine on which it is used, the balls will make contact on three points absolutely true with each other, and hence the balls produced will be absolute spheres, ready for the final oil grinding

Fig. 34 shows the ordinary type of oil grinders. These are usually placed in groups of three. The machines are provided with a quill, on which a rack is cut for raising and lowering the head by means of the lever shown projecting at the front of the machine The machines run about 450 revolutions per minute. The oil grinding constitutes the final finishing operation, and requires considerable skill The operator must know just how much oil and emery to use, and how long to run the rings so as to make the balls round up

Assume, for example, that a man is to finish grind balls ¼ inch in size. In Fig. 35 is shown a diagrammatical section of the grinding rings. The circular path of the balls is usually 16 inches in diameter. A half circular groove is cut in the bottom ring, as indicated, and a small channel is cut at the bottom of the groove to allow the oil and emery to reach the bottom of the ball. The top ring is simply a cylinder shrunk onto a plate. This plate can be used over and over again, by merely breaking off the cylinder when used up and shrinking a new ring in place. The upper cylinder has a shallow groove in it for the balls. After the balls have been placed in the ring, the oil and emery are poured in, and the upper ring is lowered onto the balls, the machine then being ready to start. The ¼-inch balls should have 0.006 inch left for the finishing operation. The operator gages the balls and sets his clock on the head of the machine as many minutes ahead of the clock in the room as he knows will be required to obtain very nearly the final size. At this time he must stop the head and again measure

the balls. The operator runs three heads, and as each head finishes its work at different intervals, he has ample time to stop any one head and take out three or four balls from different parts of the ring. After washing them in benzine, he measures them with his micrometer, testing both the size and roundness, if not to size, he replaces them and applies the required amount of oil, emery and speed, until he

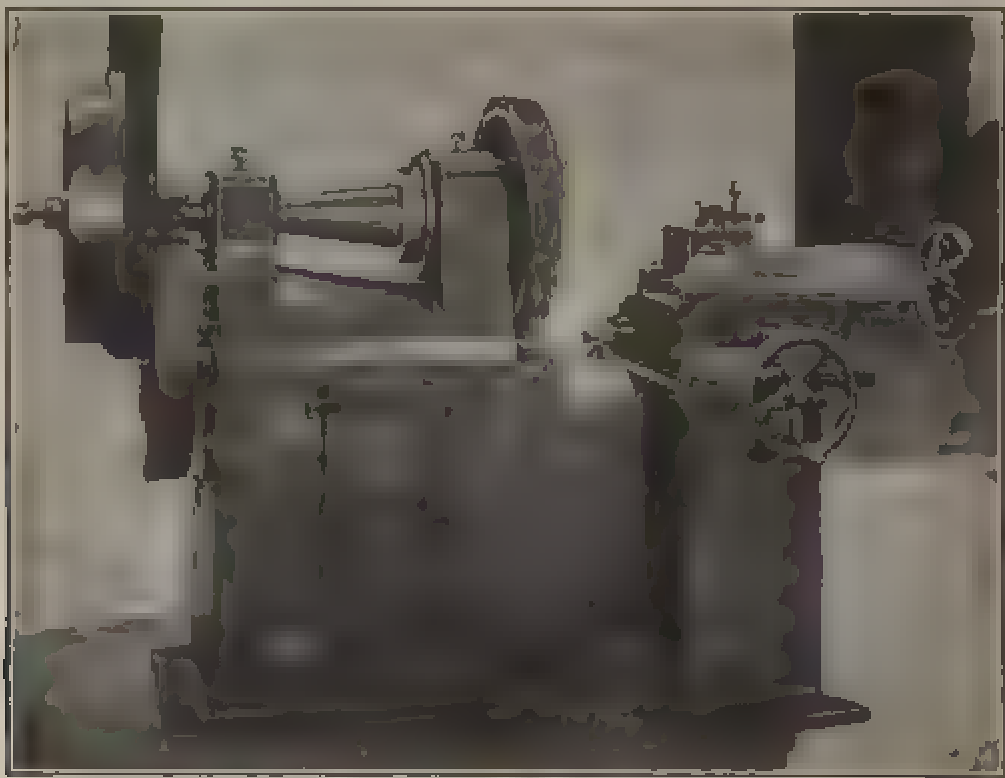

Fig 36. Ring Turning Lathe for Dressing the Oil Grinder Rings

obtains a ball that is as nearly perfect as possible in all respects.

The grinding ring should be of porous medium soft cast iron, as the oil grinding is merely a lapping process, and the ring must wear away to allow the balls to round up On account of the larger diameter at the outside Y than at the inside X of the balls, Fig 35, there is a greater peripheral speed at the outside. This causes the balls to move in a spiral path, as they revolve, so as to bring all points of the surface in contact with the ring The operator, when using a new ring for the first time, must make allowance for the ring not having become penetrated with emery, and also for its being cold Later the output can be greatly increased The heads on the grinders must be kept in perfect alignment, so that the balls will be ground on the entire circumference of the rings.

Fig. 36 shows a special ring turning lathe for dressing the oil grinder rings. It is necessary that these rings be free from chatter marks and imperfections of any kind, so that even the first sets of balls ground by them will be perfect, otherwise the first balls would have to be classified as seconds or thirds on account of poor grinding.

CHAPTER III

INSPECTING, GAGING AND TESTING OF BALLS

In the present chapter, the inspection, grading, gaging, and testing of the balls are described, and a few points given for the benefit of the user and purchaser of steel balls.

The Burnishing and Tumbling Processes

When the balls come from the oil grinders, they have a dull finish and must be burnished or tumbled. The burnishing can be done in the oil grinder with a set of rings having grooves in them the exact size of the balls. A light oil is used, and after a very short run of the machines, a finely polished surface will be produced. This process, however, is expensive, and the ordinary tumbling method is most generally used. The tumbling barrel universally adopted is of the regular iron tilting type. The balls are placed in the barrel in sufficient quantities so that, when they roll over and over, their weight will cause enough friction between them to polish them. A polishing material is placed in the barrel, and the latter is allowed to run at least ten hours to produce a good surface. The balls are then cleaned off by tumbling them in sawdust, and later placed in another barrel with finely cut kid leather. This final tumbling brings out the high polish.

Inspection

The balls are now ready to be inspected, which is done almost exclusively by girls. The skill and rapidity which can be obtained in doing this work is certainly most remarkable. One girl can inspect fifty thousand ¼-inch balls in ten hours. This inspection is done on glass plates which are about ten inches square and inserted in a frame so that the balls cannot roll off. The under side of the glass is painted so as to reflect the light. The plate is about half filled with balls and is placed upon a box which is titled slightly towards the inspector. This causes the balls to always roll to the front. The inspector holds in her hand a magnet resembling in shape a knitting needle. The end is sufficiently magnetized to raise one ball of the size being inspected from the glass. In the other hand the inspector holds a piece of heavy white paper 4 inches wide by 8 inches long, which sheet slides under the balls. This makes the balls revolve, and with the magnet defective balls are picked out. The defects consist of pits, bands, dents, scale, rough grinding marks, etc.

The different grades are separated in boxes, placed to the right of the inspector, and they are [illegible] ferent purposes according to the requirements pl[illegible] evident that different grades of balls may [illegible] that ball bearings are employed in su[illegible] ich as bicycles, clothes-wringers,

After the balls have been inspected for defects they are rolled back and forth on the glass plate in order that those that are out of round may be picked out. As the balls which are not perfectly spherical will take a zigzag motion when rolling down the plate, and the true balls will run straight, it is comparatively easy for the inspector to pick out the imperfect ones. An expert inspector does not stop each time she picks up a ball to place it in the boxes, but will usually toss it into the palm of her hand, which will generally hold all of one grade that she will pick out from the batch of balls on the plate. Balls larger than ¾ inch in diameter are generally taken up by hand and looked over. Those that are out of round in the larger sizes are taken out while measuring the balls.

Grades of Balls

Balls are generally graded into four main classes, known as alloy, and A, B, and C grades. The steel for the alloy balls contains chromium, and these balls have the greatest crushing strength. They must be absolutely free from defects as regards material and finish, and must not vary in size more than 0.0001 inch. Balls classified as A-grade are made from high-grade tool steels, accurately finished, and thoroughly inspected, and must not vary over 0.001 inch above or below the exact dimension. The balls known as B-grade are the seconds taken from the two higher grades mentioned. These are the balls which show slight, almost invisible, defects, and which vary from 0.001 to 0.002 inch. The C-grade, commonly known as hardware balls, are those picked from the higher grades when these show a defective surface. Whether these balls are gaged or not depends upon the use to which they are to be put.

The Gaging of the Balls

After the inspection, the balls are automatically gaged, the gaging being done in a gaging machine in which the balls are fed from a hopper and allowed to roll down between two hardened straightedges and to fall into tubes which carry them to the proper drawer, as indicated in Fig. 37. This illustration shows the Grant ball measuring machine. At *A* is shown the automatic dropping machine, and at *B* the delivery spout through which the balls drop into the measuring slides *C*, provided with a longitudinal slot or opening *O* between them. The sides of the slot may be accurately separated any desired amount by the micrometer adjusting screws provided at both ends. Consequently, the flare of the slot may be adjusted so that it is possible to determine exactly what the diameter is of the balls that will drop into each of the tubes and drawers beneath the measuring slide as the balls roll down along it.

As is clearly shown in the illustration, pockets are arranged successively beneath the inclined slot, and are connected by pipes with the drawers of the cabinet underneath. It is evident that in this w—
of the same size will go into the ... 'er each
that go into the middle drawer ...

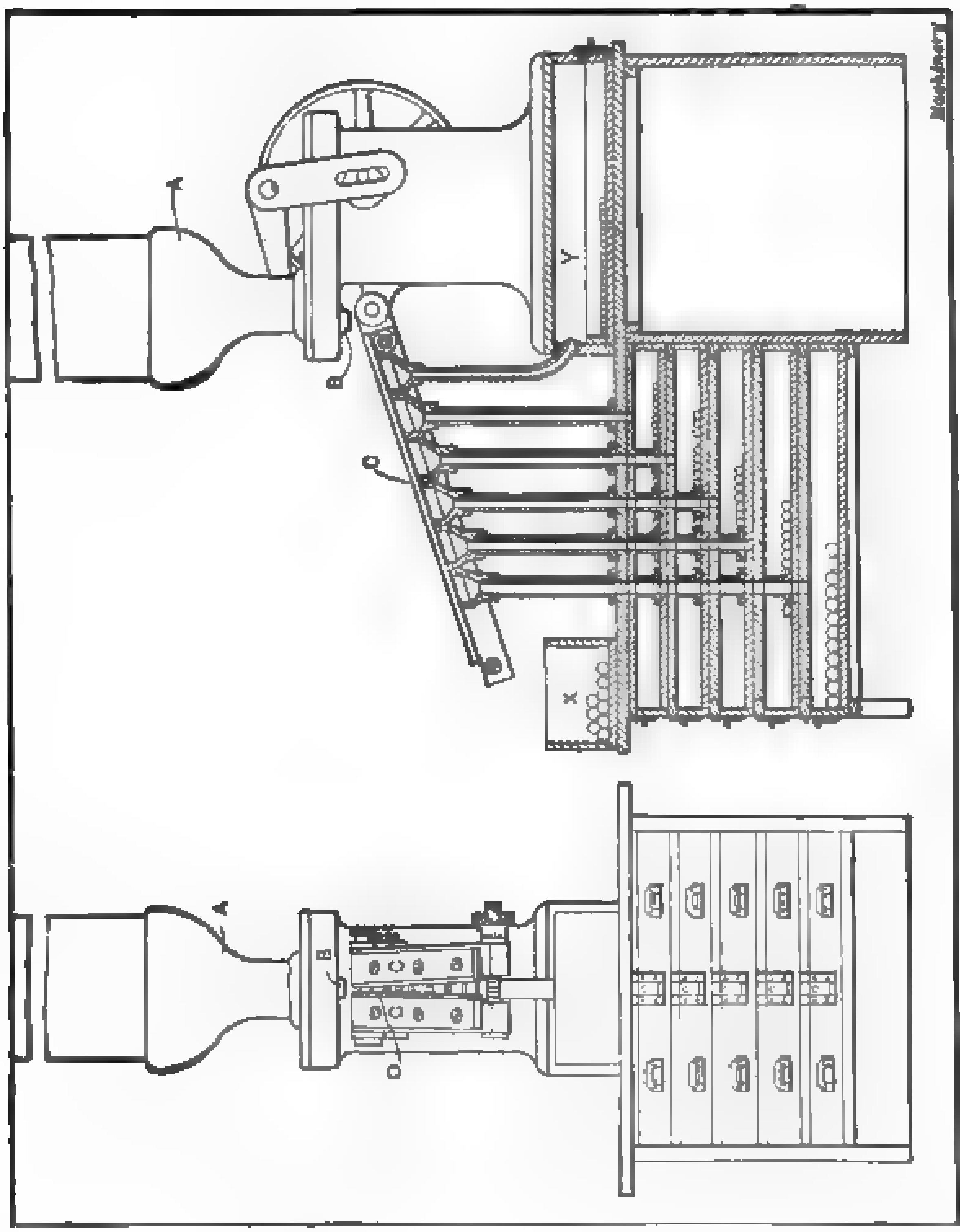

Fig. 37. The Grant Ball Measuring Machine—U. S. Patent No. 538,456

go into the upper drawers being those that are too small, while the large balls will go into the lower drawers. The balls that are entirely too large will run down the full length of the measuring slide and will be deposited in the box *X*. Those that are deposited in the drawers of the cabinet will be from 0.0025 to 0.005 inch too large or too small, according to the setting of the slides.

The exact arrangement of these measuring devices varies somewhat. In Fig. 38 is shown a group of the type of machines just described. ...ck is run through the center of the machine. In this rack, directly ... hopper, there is a hole having a bushing in it of the size ...e gaged. The ball drops from the hopper into this bush... forward until it comes to an opening which is con-

nected with a tube for carrying the ball to the measuring slides. The rack is operated by a sector of a gear mounted on a shaft having an eccentric pin on one end and a pulley on the other. Inside of the hopper there is a small tube which is operated up and down by two levers, one being attached to the eccentric pin and the other to the tube. This arrangement prevents the balls from clogging so that the bushing in the rack is always ready with a ball to carry forward thereby constantly feeding balls to the measuring slides.

In Fig. 39 is shown a Grant machine with the measuring slides removed. This particular machine is worked by a worm and worm-wheel instead of by a rack. There are two disks, beneath the balls in the hopper, the upper one of which is keyed to the shaft fastened to the worm-wheel and hence revolves. This disk has a series of holes

Fig. 38. A Battery of Grant Gaging Machines

drilled near the periphery, these holes being 0.005 inch larger than the ball to be gaged The lower plate has a hole in it directly above the measuring slide, so that when the upper disk carrying the balls presents a hole directly above the hole in the lower disk, the ball will drop through the hole and tube into the measuring slide. As the hopper is full of balls there is a liability of clogging, because two balls may have a tendency to drop through the hole at once when the opening is presented. The clogging tendency is overcome by a cut-off made of a thin piece of tool steel with beveled edges, which covers two holes in the revolving disk, the holes covered being the one directly over the lower disk and the one next to follow. This prevents jamming of the balls. The remainer of the machine and cabinet is substantially the same as in the machine shown in Fig. 37.

In the Putnam gaging machine the hopper is worked pract.

same as in a machine for slotting screws. Fingers raise the ball, allowing it to fall into a trough, and then through a tube onto the measuring slides.

This mechanical gaging and sorting of balls is applied to all sizes up to and including $\frac{3}{8}$ inch. The large sizes are measured by hand by micrometers. The girls employed for this work pick them up one by one and measure each ball separately over several diameters, throw-

Fig. 39. A Modified Type of Grant Measuring Machine, with Gaging Slides removed

ing them into small boxes placed before them, each of the boxes containing a certain size of balls between the limits of measurements adopted. This work is very rapidly done, as the operators become very skillful.

Counting the Balls

The next operation is the counting and boxing of the balls which at first sight might be assumed to be a tedious and very slow operation. So it would be were it not for the mechanical means adopted for doing this work. Balls up to $\frac{3}{8}$ inch in diameter are counted by means of a counting board, as indicated in Fig. 40, which has holes sunk in it 0.010 inch larg[illegible] the ball. Around the board is tacked a narrow strip of wood [illegible] the balls from rolling off. The balls are then poured upon th[illegible] all balls which do not find a hole to enter are allo[illegible] is a predetermined number of holes in the [illegible] knows how many balls she has, and s[illegible] the counting board into a

pasteboard box in which the balls are packed. In this way one girl can easily count a million balls a day and do other work besides.

The pasteboard boxes are made of a telescoping form, lined with paper which is free from acid and which has previously been soaked in an anti-rust compound. The balls, which have a very high polish, would otherwise easily rust on account of sweating, which is caused by the difference in temperature of extreme heat and cold. It is very essential that steel balls should be kept in a room properly heated.

The Testing of Balls

The testing of a steel ball for crushing strength should be done between hardened plates by placing three balls in a tube into which they nearly fit. The center ball is the one that will be tested. The

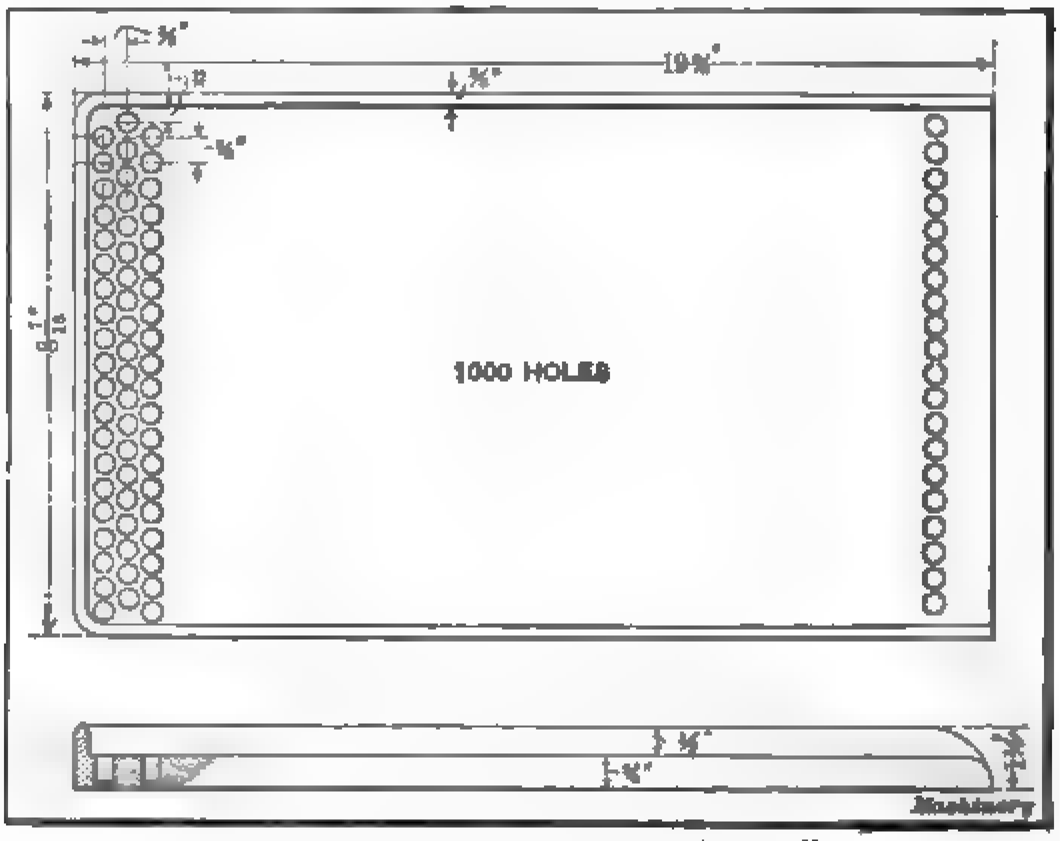

Fig. 40. Counting Board for 5/16-inch Balls

upper and lower balls will, of course, sink into the plates, and this will give them more of a surface bearing than the middle ball, which bears only in two points upon the upper and lower balls; hence the middle ball will ordinarily give way first. As the pressure is applied, a double pressure cone will be formed inside of the ball, this cone having its apexes where the outside balls bear on the middle ball. If properly hardened, a ball will break into several pieces. This method is the proper way to test a ball, but there seldom are two balls that will stand exactly the same load when tested. This is caused largely by the methods in which the ball blank is made. As will be remembered from the description of the making of the blanks in the first chapter of this book, the balls in the forging process are much more compact at what might be called the "poles," that is, where they join the next ball forged, than at the "equator." Therefore, if the center ball

being tested has the point of contact on the "equator," it will not stand within ten or twenty per cent of the load that it would stand if the points of contact were at the "poles." The same method of reasoning may be applied to stamped and turned balls.

Through the means of this testing operation and the appearance of the fracture, it can be determined whether the balls have been properly hardened. Every batch of steel, no matter how carefully made, usually requires a slightly different treatment in hardening, and what this treatment is must be determined by the man responsible for the hardening work. The accompanying table shows the crushing load ordinarily required by ball manufacturers for regular tool-steel balls.

Size of Ball in Inches	Ultimate Strength of Ball in Pounds	Size of Ball in Inches	Ultimate Strength of Ball in Pounds
1/16	390	5/8	39,000
3/32	875	3/4	56,250
7/64	1,562	13/16	66,000
1/8	2,450	7/8	76,000
3/16	3,496	15/16	88,000
7/32	4,780	1	100,000
1/4	6,215	1 1/8	125,000
5/16	9,940	1 1/4	156,000
3/8	14,000	1 1/2	225,000
7/16	19,100	1 5/8	263,000
1/2	25,000	1 3/4	306,000
9/16	31,500	2	400,000

The figures above have been adopted after a great many years of testing and are considered by the manufacturers safe figures with which to calculate. Of course, in selecting a ball for a bearing, a factor of safety of ten should always be adopted unless the bearing is used in an extremely narrow space. The grooves in which the balls run when heavy loads are imposed should be round and not of V-form. No figures can be given relating to tests of balls made from alloy steel, because these steels give such irregular results that the manufacturers have been unable to compile any data that would be in any way satisfactory. It is, however, safe to state that the alloy-steel balls will stand from 25 to 50 per cent more than the regular tool-steel balls.

Balls of Other Materials than Steel

Balls are made of a great many other materials, brass and bronze, for instance, being used extensively for oil-well devices where acid is found in the crude oil. Such balls are also used in valves where the material to be pumped will rust steel balls and cause corrosion, and also in electrical work. German silver balls are used in Yale locks to prevent corrosion when used on shipboard or in other places where they would be subjected to the damp sea air. Casehardened machine steel balls are used extensively in agricultural implements and similar ar paratus on account of being inexpensive. Chilled cast-iron balls used in turntables, trucks. and for similar requirements.

Points for the User and Purchaser of Steel Balls

In the following the essential points relating to the manufacture of balls which should be kept in mind by a purchasing agent or consumer are given. Nothing but a tool-steel ball should be used for high-grade work, and it is very important that it be properly heat-treated. Do not be deceived by a finely polished ball, as high polish and deep scratches (which show only under a magnifying glass) do not necessarily indicate a good ball. In fact, the outside appearance has little or nothing to do with the wear of a ball, for a dull looking ball may be just as good as one with the highest polish. The polish is merely the result of the tumbling process.

The first requirement is that the right material has gone into the balls. It costs but little to have the steel analyzed so that the purchaser may know whether he is getting a tool-steel ball or a machine-steel ball. The fact that the ball has only a point bearing makes it the more important that it be made from good material in order to stand the pressure to which it may be subjected. Casehardened machine-steel balls ought not to be used when heavy duty is required. Naturally there is some difference in the quality of the steel that costs thirty-five dollars per ton from that which costs one-hundred-fifty dollars per ton.

It is true that a ball can be casehardened very deeply, in fact, almost through to the center, but it should be remembered that casehardening implies adding carbon to the steel under a high heat, which causes the pores in the steel to open so that the carbon can enter. The process, however, does not remove the injurious elements, such as phosphorus, sulphur and silicon, of which the cheaper steel contains a large percentage. It is, of course, perfectly satisfactory to use casehardened balls for many purposes, but when it comes to a really high-grade article, the highest class of steel is to be preferred.

In order to determine whether a ball has been properly heat-treated, place the finished ball in a piece of waste on an anvil and break it open with a heavy blow. The waste prevents the pieces from flying around. If the ball is properly heat-treated, the break will show a soft silky-appearing surface—the grain of the steel being fine. If it has not been heat-treated, it will look coarse and granular, having more the appearance of cast iron.

If during the test the ball should break in half, it would indicate that it had not been properly drawn after hardening, but was still subjected to internal stresses. If such a ball is placed in a bearing, it will easily break if subjected to a severe shock or strain. If a ball has been properly drawn it can be touched with a fine Swiss file, and under the blows of a heavy hammer it will dent slightly and break into several pieces.

Balls over 5/16 inch in diameter that have been turned or headed should not be used for heavy duty, as they are not as good as balls for which the blanks have been forged. The headed ball, on account of the severe shock to which the metal is subjected when cold, cannot be treated so as to stand the strain that the forged ball will stand. A

turned ball is cut from a rod which is rolled, so that the grain of the steel is in a lengthwise direction; hence when a ball is turned from this bar the surface of the ball consists of a mass of exposed fibers. When put under a heavy strain, as in a thrust bearing, it will pit and flake off. The surface of the ball should be smooth, that is, all the marks from the rough-grinding process should have been removed in the finish-grinding. If this has been done it can be readily determined by a magnifying glass.

A ball made from a forged blank cannot be hardened properly unless the decarbonized surface has been wholly removed. Some manufacturers attempt to keep the forgings as small as possible in order to save material and time in grinding, and in many cases it is then impossible to remove all of the decarbonized surface. Hence when the ball is hardened, rough marks and soft spots can be detected. The soft spots are much brighter than the properly hardened surface.

If balls are to be used for special purposes, this should be designated in the order sent to the ball manufacturer. In order to be able to supply a ball that will give satisfaction, it is necessary that he be furnished with information as to what the ball is to be used for, the speed and load at which it will be used, and the kind of bearing employed. Then the balls can be drawn to a degree of temper adapted to the particular purpose in view, and thus satisfaction can be guaranteed to the purchaser. It is also very important to see that the balls that are furnished are not out of round, as this would cause the bearings to "catch" and "jump." The resulting bearing will run unsatisfactorily, and will rattle on account of the fact that the balls are loose at one point and tight at another. The actual size of the ball does not make a great deal of difference, provided the balls are all of the same size. In other words, in a lot of one-hundred-thousand balls, if they are found to be 0.0005 or 0.001 inch under size they will give satisfaction if they are all used before the next shipment can get mixed up with them.

It has already been mentioned that the temperature of the room in which the balls are stored must not be too low. The temperature of the stock-room should be kept the same at all times, and on Sundays and holidays, when the factory is closed, it should be especially heated, for a ball which becomes very cold and then is brought back to a warm temperature will soon begin to rust and cause a great deal of trouble.

Summary of Ball-making Processes

In order to fix in the reader's mind the various processes that a ball passes through, from the time that the blank is produced from the rough stock until the finished ball enters the stock-room, a general summary of the processes described in the three chapters comprising the present treatise on the manufacture of steel balls will be given.

There are several methods for producing the ball blank. One is that of turning the ball blanks in a special automatic machine. This method is rapid and makes it possible to produce a blank which requires less

grinding than the blanks produced by other methods, but on account of the fact that the fibers of the stock from which the blank is turned are cut and exposed at the surface, a ball so made is of inferior strength after hardening as compared with balls the blanks of which are made by other methods.

Another method commonly used for producing ball blanks is to form the blank in a heading machine. A bar is fed into the machine and pieces of the required length are cut off and headed between dies to a ball shape. This is a very rapid method, and balls up to, say, 5/16 or ⅜ inch in diameter can be made advantageously by this process. As there is no waste, this process for smaller sizes of balls must be deemed the best as well as the cheapest of the methods used at the present time.

The best method of making ball blanks from ⅜ inch to 2 inches in diameter is known as string forging. This method is very extensively used and the balls so produced, when properly heat-treated, are strong and tough in their structure. The balls which have been produced by the heading or forging process must have the fin or flash ground off before they pass to the grinding machines. The process by means of which the fin is removed is called "flashing," and the machine in which it is done is ordinarily termed a "rotary" file. Large balls are flashed separately in a special fixture by an ordinary emery wheel.

The balls are now ready for the dry-grinding process, the grinding being done by an emery wheel acting upon the balls which are held and rotated by suitable means. After being dry-ground, the balls are annealed and then hardened, the smaller balls being quenched in cottonseed oil, while the larger ones are immersed in brine. After hardening, the balls are washed in boiling soda and then tempered in oil.

After the tempering, the balls are ready to return to the finish dry-grinding department, and are finish dry-ground in machines of the kind that performed the rough dry-grinding, but a finer grade of emery wheel is used. From the finishing dry-grinders the balls pass to the oil grinders, where the final grinding operation is performed and where the balls are brought to exact size. The oil grinding operation is practically a lapping process, no grinding wheel being used. The machine has merely two plates, one of which is grooved, between which the balls roll. The grinding medium is fine emery and oil.

When the balls have been brought to size in the oil grinders, they are given their final finish either by burnishing them in machines similar to the oil grinders, or by being tumbled in a tumbling barrel with a polishing medium. Next they are tumbled in sawdust, and finally in a barrel with cut-up kid leather to obtain the high polish. The balls are then inspected, graded and gaged. The smaller balls are gaged in gaging machines, while the larger are measured by micrometers. Next the balls are counted and packed into boxes and sent to the store-room, which finishes the operations.

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HIGH-SPEED AND CARBON TOOL STEELS

CONTENTS

CHAPTER I

TOOL STEEL FOR THE UNITED STATES NAVY

Previous to 1909, each of the U. S. navy yards prepared requisitions for the purchase of tool steels for its own purposes. These requisitions either specified that proprietary material should be purchased or that the award of contract be based on information obtained by a test of some description on samples submitted by the bidders. By this method, there could be no uniformity in the specifications of the navy yards, and in order to centralize purchasing and to standardize the tool steels, a tool steel board recommended that the Philadelphia Navy Yard be made the purchasing station. This action was taken in 1909 and at that time specifications were drawn up for one high-speed steel and three grades of carbon steel.

The chemical composition required for the high-speed steel differed from that of any of the commercial brands, but the chemical composition of each grade of carbon steel corresponded to that of commercial tool steels. The three grades of carbon tool steel varied principally in their carbon content, in order to adapt them to the purposes for which such tool steels are generally used. The contracts were awarded to the lowest responsible bidder who was able to meet these specifications for tool steel of a chemical composition within the specified limits. The specifications required physical tests in addition to chemical analysis, as a part of the inspection, but these tests did not give decisive results and proved conclusively that it was advisable to revise the existing specifications. This step was taken because these specifications did not provide a means of ascertaining the relative merits of the tool steels offered by the different bidders, or of learning whether there were other tool steels that were superior to those within the specified limits of chemical composition.

In order to overcome these objections, a set of specifications was finally drawn up which are given in a later section of this chapter, as presented by Mr. L. H. Kenney in a paper before the Society of Naval Architects and Marine Engineers. These specifications require the bidders to submit samples of the tool steels which they offer for sale. The samples are manufactured into tools and subjected to physical tests devised to determine the relative merits of the different steels. The data obtained in this way constitute the basis for the award of contracts. In this set of specifications the chemical compositions are given the maximum and minimum limits, the purpose being to indicate to the bidder the kind of tool steel that is wanted, but the physical
...e the real basis for the award of contracts. The object
...n is to introduce competition as to the quality of tool
...simply having competition in price, to provide a

means of learning something about the relative merits of the commercial tool steels, and to take advantage of the developments and progress made by the manufacturers in this industry. By this means, definite information can be obtained concerning the qualities of the different tool steels before the contracts are awarded for their purchase.

The study of tool steels which has been made possible by the adoption of this set of specifications is conducted under the direction of the engineer officer of the Philadelphia Navy Yard. The subject is divided into two general classes, one of which covers the high-speed or tungsten steels and the other the carbon tool steels.

Tungsten Steels

The limits of the chemical composition called for under the revised specifications were varied from those required by the original specifications in order to permit bidders to submit proposals on their commercial or standard tool steels, and the feature of a selective test was introduced. This selective test provides means for investigating the relative suitability of the different tool steels offered by bidders for the class of work for which the steel is required, and the recommendation for the award of contract is based on the information thus obtained. In order to obtain samples of tool steel for the selective test, the specifications require each bidder to furnish a sample bar of the steel which he offers. This bar is delivered to the engineer officer, under whose direction the selective tests are conducted. The heat-treatment of the tools, their chemical analysis, the condition of the physical test, and the computations necessary to determine the award of contract constitutes the selective test. A lathe tool selected for the physical test is kept cutting without lubricant until it fails by the sudden breaking down of the cutting edge, due to heating caused by friction of the chip. A record of the elapsed time of the run is made, which is the principal variable, other conditions being kept constant. After failure, each tool is reground, care being taken to remove the effect of the heat produced during the previous cut; the tool is then tested once more until it breaks down, as previously described. After the conclusion of this cut, the tool is reground and tested a third time.

During the test, a voltmeter and ammeter are used to determine the power supplied to the motor which drove the test lathe. This is done in order to obtain a measure of the work done by the nose of the tool. The ammeter readings vary for the different tools, due principally to slight variations in depth of cut and cutting speed, which indicates that the work done by the different tools is not the same. In order to allow for this difference in computing the selective factor, a quantity was introduced called the "work value," which is [illegible] product of the mean elapsed time of r[illegible] of [illegible] and the mean watts required to [illegible] watts. The work value, theref[illegible] by the tool. The work value[illegible] given steel that were tested[illegible]

least squares. The work value divided by the price per pound gives the "selective factor" for the test, the contract being awarded to the manufacturer of the steel having the highest selective factor.

In conducting the selective tests with tungsten tool steels, five tools made from the same sample bars are stamped with an index number which is assigned to each sample, and with consecutive numbers for the tools of each sample. The tools are hand-forged to the No. 30 lathe tool form of the Sellers system. The following day the tools are heat-treated. For this purpose, one oil furnace is maintained at a temperature of from 1600 to 1700 degrees F. and another furnace at from 2400 to 2450 degrees F. The cutting ends of the tools are preheated in the low temperature furnace and then transferred to the high temperature furnace. After the tools are removed from the heat-treating furnace, they are cooled by dipping the ends into oil. The oil is agitated by compressed air and is cooled to maintain it at as nearly an even temperature as possible. Oil is used for quenching because it is less noisy and less expensive than compressed air, and tests which have been made also appear to indicate that better results are obtained by using oil as a quenching medium. The tools are cooled in oil until they are black hot, when they are removed and placed on the cooling table. All the tools are tested on a single nickel-steel forging because the characteristics of nickel steel forgings vary. The depth of cut, feed, and cutting speed are kept constant throughout the selective test, thus making the cutting time the principal variable. In regrinding it is found necessary to remove about 3/32 inch of the tool to get rid of the effects of heating.

Carbon Tool Steels

The information obtained from the selective tests conducted on samples of high-speed steel indicated that it was advisable to revise the requirements for carbon tool steels which were given by the original set of specifications, and a method of conducting selective tests, similar in character and purpose to those previously referred to, was adopted for use with this class of steels. Four classes of carbon tool steel were selected which varied principally in their carbon content. The specifications require the conditions of the selective test to be maintained as nearly constant as possible for each class of steel. The elapsed time of the run is the principal variable in the test, the tools being operated until they break down. Milling cutters are used for the tests on steels of Classes 1 and 2 (see table), and the duration of the run consists of the total time that the cutters are operating, but it does not include the time required to return the milling machine table to the starting point and to set it for the next cut.

A cape chisel is used for the selective test on carbon tool steels of Class 3. In some of the early tests, trouble was experienced through [illegible] the shank of the hammer end of the chisel. This trouble has [illegible] as the selective tests are concerned, and also in [illegible]ating about ½ inch of the hammer end of the [illegible]enching the tool by dipping about ¾ inch

into brine for a few seconds and then the entire tool. The cutting end is treated at the same temperature as the hammer end, and the temper of both ends is drawn by submerging the chisel in a molten lead bath at the desired temperature. In making these tests, it has been found that the heat-treatment does not extend back far from the cutting edge and there is only a short distance on the tool where the maximum cutting life can be obtained. If the chisel shows poor results on the first test, indicating that the temper has not been drawn sufficiently, the second test usually gives more satisfactory results, while the third test may show that the chisel is too soft.

A button-head rivet set is used for testing Class 4 of carbon steel. The set is heated to the desired temperature and quenched in brine, after which the temper is drawn in a lead bath. Each set is used to drive a certain number of hot rivets and an observation of its condition is made after the test. This test is not carried to destruction, however, as in the preceding tests and consequently does not yield decisive results.

The results of the tests of carbon steels of Classes 1, 2 and 3 vary considerably. As a result, it has not been found advisable to adjust these results by principles of least squares. After the tests have been completed, the data are gone over and those results which vary widely from the average are rejected. The selective factor for the different steels is then calculated and the contract awarded to the manufacturer whose steel shows the highest selective factor.

Each sample of carbon tool steel submitted for selective test is tested to determine the decalescent point in order that it may be hardened at a suitable temperature. In heat-treating, the temperature of the tools is raised to a point slightly above the decalescent point and they are then quenched in brine. After quenching, the temper is drawn in a lead bath, after which the cutting tools are ground ready for the selective test. The milling cutters used for making the selective tests for carbon tool steel were of the newer coarse teeth type, recently introduced. The distinctive feature of these milling cutters is the large pitch of the teeth, thus providing a large clearance for the chips. The cutter is operated at a speed of 370 revolutions per minute with a feed of 20 inches per minute and a depth of cut of 0.080 inch through the full travel of the milling machine table. The table is run back to the starting point and reset as often as necessary until the failure of the cutter occurs. The cutter is run without lubricant, in order to make the tests as severe as possible.

Specifications for Tungsten Tool Steel

1. *Class* 1.—Lathe and planer tools, milling machine tools, and in general all tools for which high-speed steel is used.

Specifications for Carbon Steel

2. *Class* 1.—Lathe and planer tools, and tools requiring keen cutting edge combined with great hardness, for finishing shrinkage dimensions on nickel-steel gun forgings, drills, taps, reamers and screw-cutting dies.

3. *Class* 2.—Milling cutters, mandrels, trimmer dies, threading dies, and general machine-shop tools requiring a keen cutting edge combined with hardness.

4. *Class* 3.—Pneumatic chisels, punches, shear blades, etc., and in general tools requiring hard surface with considerable tenacity.

5. *Class* 4.—Rivet sets, hammers, cupping tools, smith tools, hot drop-forge dies, etc., and in general tools which require great toughness combined with the necessary hardness.

CHEMICAL COMPOSITION

Tungsten Tool Steel	Class 1, Per Cent Limit	
	Maximum	Minimum
Carbon	0.75	0.55
Chromium	5.00	2.50
Manganese	0.30	0.05
Phosphorus	0.015	....
Silicon	0.30	....
Sulphur	0.03	....
Tungsten	20.00	16.00
Vanadium	1.50	0.35
Iron	*	*

Machinery

*Remainder

Carbon Tool Steel	Class 1, Per Cent Limit		Class 2, Per Cent Limit		Class 3, Per Cent Limit		Class 4, Per Cent Limit	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
Carbon	1.25	1.15	1.15	1.05	0.95	0.85	0.85	0.75
Chromium	†	†	†	†	†	†	†	†
Manganese	0.35	0.15	0.35	0.15	0.35	0.15	0.35	0.15
Phosphorus	0.015	....	0.015	....	0.02	....	0.03	....
Silicon	0.40	0.10	0.40	0.10	0.40	0.10	0.40	0.10
Sulphur	0.02	....	0.03	....	0.02	....	0.025	....
Vanadium	†	†	†	†	†	†	†	†
Iron	*	*	*	*	*	*	*	*

Machinery

*Remainder †Optional

Physical Tests of Tungsten Tool Steel

6. *Class* 1.—The sample bar will be forged into five tools, treated and ground to the No. 30 form of the Sellers system of lathe tool forms. Each tool will be tested on a nickel-steel forging of about 100,000 pounds tensile strength, with a cut ¼ inch deep, 1/16 inch feed, and a cutting speed of 50 feet per minute. Each tool will be twice reground and retested. A record will be made of the length of time each without a lubricant or cutting compound before it is ruined.

Physical Tests of Carbon Tool Steel

7. *Class* 1.—Five 7/16-inch diameter, 4-tooth facing mills will be made from the sample bar and tested on a piece of ⅝-inch ship's plate without lubricant. Each mill will be run until it is so dull that it breaks either in the teeth or in the shank. The depth of cut will be 0.08 inch, the revolutions per minute of the mill will be 370, and the feed of material 20 inches per minute. A record will be made of the length of time each mill operates.

8. *Class* 2.—Same tests as *Class* 1.

9. *Class* 3.—Five ½-inch pneumatic chisels will be made from the sample bar. Each chisel will be tested on a nickel-steel plate with a cut 1/16 inch deep.

A record will be made of the distance each chisel cuts with a lubricant before it is ruined.

10. *Class* 4.—Two ½-inch rivet sets will be made from the sample bar. A record will be made of the condition of the sets after a certain number of rivets have been driven.

11. *Modification of Tests.*—Any or all of the above tests may be modified at the discretion of the engineer officer.

12. *Method of Manufacture.*—The tool steels shall be made in either the electric or crucible furnace. The bars must be forged or rolled accurately to the dimensions specified, free from seams, checks, and other physical defects and of homogeneous compositions. The tungsten tool steels shall be delivered unannealed, unless otherwise specified, and the carbon tool steels shall be delivered annealed unless otherwise specified. The bars shall be delivered in commercial lengths and short pieces will not be accepted unless so specified.

13. *Stamps on Material.*—Each bar or piece of tool steel, whether sample bar for "selective test," "acceptance test," or material delivered under contract, shall be stamped with the manufacturer's name, his trade name and temper index, and in addition identification stamps of the kind and class of tool steel as given in these specifications. The tungsten tool steel, Class 1, shall be stamped T-1, and the carbon tool steels, Classes 1, 2, 3, and 4: C-1, C-2, C-3, and C-4; the letters to be about 3/16 inch high. If the bars are longer than about 4 feet, the above stamps should be placed at intervals of about 3 feet along the bar.

14. *Acceptance Test.*—Sample bars for "acceptance test" will be taken from the material delivered under contract to the general storekeeper, Navy Yard, Philadelphia, Pa., or if the material is inspected at the place of manufacture, the inspector will forward sample bars of the dimensions called for to the storekeeper, who will forward them to the engineer officer for him to arrange the tests indicated by these specifications and recommend the acceptance or rejection of the material. If the material does not prove to be equivalent to the sample bar furnished with proposal this will be considered sufficient cause for rejection. The contractor shall replace the shipment within two weeks, if practicable, after the receipt of notice of rejection. The

sample bars used for this test will be credited the contractor if the material under test is accepted.

15. *Defective Material.* If material, when being manufactured into tools, develops physical defects which could not be detected by inspection, such as "cracks," "pipes," etc., the manufacturer of this steel shall replace, without cost to the government, such defective material.

16. *Reservation and Alternate Proposals.* The right is reserved to reject any or all proposals.

Bidders may submit proposals on tool steel which differs from the composition and method of manufacture specified, provided this is clearly stated in their proposal, and provided they furnish the engineer officer with a statement of the exact chemical composition and method of manufacture of the tool steel. This information will be considered confidential by the engineer officer if the bidder requests it. The tool steel will be tested if, in the opinion of the engineer officer, it is considered suitable for the purpose intended.

17. The engineer officer will, after the prescribed tests have been made, recommend the award of contract for the steel or steels which, in his opinion, it is to the best interest of the government to purchase, due consideration being given to the cost of the material. The relation of the tests and the price of the material will be the basis for selection.

18. *Selective Test.*—Each bidder shall furnish with his proposal a sample bar of tool steel stamped as called for under heading "Stamps on Material" for the "selective test." The relation of the results obtained from the tests conducted as provided for under the heading "Physical Tests" and the price of the material determine the selective factor. The dimensions of the sample bars shall be as follows:

Tungsten Tool Steel

Class 1.—¾ by 1½ inch by 5 feet long.

Carbon Tool Steel

Class 1.—⅝-inch diameter rod, 2 feet long.
Class 2.—⅝-inch diameter rod, 2 feet long.
Class 3.—¾-inch octagon rod, 5 feet long.
Class 4.—2-inch diameter rod, 2 feet long.

19. *Treatment of Samples.*—Each bidder will state in his proposal, if he considers it necessary to do so, the treatment to which the material must be subjected in order to get, in his opinion, the best results.

20. *Delivery of Sample Bars.*—All sample bars stamped as called for under the heading "Stamps on Material" must be delivered to the general storekeeper, Building No. 4, Navy Yard, Philadelphia, Pa., prior to the time fixed for opening of proposals. Sample bars delivered late will not be received. Failure to comply with the above requirements will eliminate the proposal from consideration. All sample bars will be delivered by the general storekeeper to the engineer officer for the "selective tests."

CHAPTER II

RELATION OF PRICE OF TOOL STEEL TO MANUFACTURING COSTS

It often happens that steel manufacturers receive orders with an additional remark something like this: "This steel, which costs twice as much, must give at least double the production of our present steel in the operation in which it is to be used, otherwise it will be returned." This indicates that there are many who reason that if a tool steel costs, say, 50 or 100 per cent more per pound than another, then it must be able to do 50 or 100 per cent more work to justify the price. As a matter of fact, if one steel does five per cent more work than another it is well worth fifty per cent more per pound on all usual operations. There are many ways of proving this. One is to take any machine in the shop and learn the relation of tool cost to total costs. For illustration, we have selected a lathe using tools made from 1½- by ¾-inch steel. How much high-speed steel is used a day? Our observations, estimates and averages show that the daily consumption is one-twelfth pound of high-speed steel on the average lathe, doing fairly hard work at a good speed. This is based on work requiring the tool to be ground five or six times a day. If the tools cut all day on one grinding it indicates that they are cutting considerably below capacity, although this is sometimes necessary owing to local conditions. The one-twelfth pound daily consumption of steel is arrived at in the following way:

High-speed Steel used Daily on 20-inch Lathe

Size of tool: 1½ by ¾ inches. Average number of grindings: six per day.

Steel ground away each grinding...............	1/32 inch
Steel ground away each day (six grindings)....	3/16 inch
Steel ground away each week (six days)......	1 inch (approx.)

Then the tool needs redressing. In redressing and retempering, a small piece of steel is cut off. Making liberal allowance, this waste is about one-half inch of steel.

The waste of steel in redressing is.....................	½ inch
The amount of steel ground away is (see above)........	1 inch
The weekly consumption of steel........................	1½ inch

One and one-half lineal inch by 1½ by ¾ inch high-speed steel weighs one-half pound. The daily consumption, therefore, is one-sixth of one-half pound, or one-twelfth pound.

The Daily Cost of Tool Steel

On the basis of one-twelth pound steel consumption per day, if equal quantities were used:

High-grade high-speed steel at 71 cents per pound costs per day	$0.06
Cheap high-speed steel at 48 cents per pound costs, per day....	.04
Increased first cost of higher priced steel, per day.............	$0.02

The Cost of Operating

On a lathe such as we are using for illustration.

The machinist's hourly rate, about............................	$0.36
The overhead (including power)............................	.24
The total hourly rate....................................	$0.60
The day rate (eight hours)..............................	$4.80

The Value of the Product

If the man operating the lathe which we are using for illustration turns out 100 units of work daily, each piece costs the manufacturer 1/100 of $4.80 or 4.8 cents, and just that much value is produced. If the higher priced steel enables the machinist to turn out one piece more daily, thus increasing the output only one per cent, we have the following results:

Value of one extra piece produced..........................	$0.048
Increased first cost of the steel.............................	.020
Net daily profit on one per cent increase....................	$0.028

In this case a one per cent increase would warrant buying a good grade of steel costing fifty per cent more than cheap steel.

With high-grade tool steels, increases in production as high as fifty per cent or one hundred per cent are often secured, but the object of this article is to show that a five per cent increase in production justifies paying much more than a fifty per cent increase in first cost.

Taking the same illustration from another point of view: With the higher priced steel at 71 cents per pound,

The man's time per day..................................	$2.88
The "overhead" per day..................................	1.92
Steel per day..	0.06
Daily total..	$4.86

With cheap steel at 48 cents per pound,

The man's time per day..................................	2.88
The "overhead" per day..................................	1.92
Steel per day..	0.04
Daily total..	$4.84

The total daily cost has been increased less than one-half of one per cent; one-half of one per cent of $4.84=2.4 cents. Therefore, if the higher priced steel does one-half of one per cent more work, it is the cheapest, although the price per pound may be fifty per cent higher than the steel formerly used.

Saving in Grinding

There is another point of view from which the price of tool steel should be considered, and that is the saving in grinding. Some tool steel users think that if the steel costs twice as much, it must require grinding only one-half as many times, but in the foregoing illustration, if one grinding is saved in two days, it justifies paying fifty per cent more for the steel. We arrive at this conclusion through the following: We have found that sixty cents an hour is a conservative estimate of the cost of a man's time and the overhead expense. On this basis every grinding which requires about five minutes means a loss of time and production worth five cents. The excess first cost of steel at seventy-one cents, as compared with a forty-eight-cent steel on the machine we are using for illustration, amounts to two cents a day. Therefore, if tools made from the higher priced steel save one grinding in two days, they warrant an increase of fifty per cent in the price per pound.

In addition to the profit and saving resulting from increased production and fewer grindings, there are also secondary savings to be considered. For instance, tools made from the higher priced steel will require redressing and rehardening less frequently, and the cost department knows what this means in the way of economy. Another saving results through a reduction in the amount of steel used. This has not been brought into our figures, but it should be considered in discussing tool steel costs. Less of the high-priced steel will be required than is the case where cheap steels are used.

Another important saving that is often forgotten, and which cannot be computed, is the time saved on break-down or emergency jobs. There are times in many shops when the management would gladly pay as much as the monthly tool steel bill to save an hour on a repair part, the lack of which holds up a large shipment, or stops work throughout the shop.

A number of minor savings have not been mentioned, but they are not needed to prove the wisdom of paying fifty per cent more for a steel which does five per cent more work. In conclusion, it may be stated that this method of considering tool steel costs may be applied on any machine, regardless of the kind of steel used. In nearly every case the higher priced steel, whether in ordinary tool steel grades or in high-speed steel grades, will be found cheapest if it brings about even a slight increase in the efficiency of cutting tools.

The indirect relation of the cost of the tools of production to the cost of production set forth in the foregoing, applies all along the line. The first cost of a machine is of little importance in comparison with its productive capacity during its lifetime. A lathe costing $1000 may in the course of ten years earn $10,000 for the shop in which it is used, while another of the same nominal capacity but of superior design and workmanship, costing say $1100, might earn $12,500 in the same period, or sufficiently more than the other to wipe out the original cost and the interest on the investment.

CHAPTER III

THE INFLUENCE OF HEAT ON HARDENED TOOL STEELS

By testing various samples of carbon steel in the tool steel testing machine designed by Mr. E. G Herbert, it was found by him that carbon tool steels have a very low durability at a low cutting speed, that there is an increase of durability as the cutting speed increases, and that a maximum durability of cutting speed is obtained at about 50 to 80 feet per minute. There is then a decline of durability to a very low value if the cutting speed is further increased These general characteristics are common to all tool steels that have been tested, whether of the carbon or high-speed steel type (tungsten or tungsten-vanadium varieties). All of these give, when the durability is recorded in diagrammatic form, a single- or double-peaked curve, according to the heat-treatment they have received. All show a low durability at low cutting speed, this characteristic being especially marked in the case of some high-speed steels, which latter often retain their durability at very high speeds.

It has been pointed out that the observed changes in the durability of cutting tools are mainly caused by the changes in the temperature of the cutting edge, due to the heat generated at different cutting speeds. This heat theory has been confirmed by experiments showing that changes of durability corresponding to those which occur under varying cutting speeds can be produced by varying the temperature of the tool in other ways, while the cutting speed remains constant -for instance, by varying the temperature of the water with which the tool is flooded, or by varying the depth of the cut (a heavy cut generating more heat than a light one), or by dispensing entirely with the cooling water.

The various problems that were dealt with in the experiments were as follows:

1 —It has been found by experiments on the tool steel testing machine that all tool steels, without exception, have a very low durability, and are very quickly blunted when cutting under water at low speeds and fine cuts, that is, under conditions which preclude any considerable heating of the cutting edge, and it has been found that any alteration in the cutting conditions which tends to increase the temperature of the cutting edge results in an increased durability of the tool What, if any, are then the correlative changes in the physical properties (strength, hardness, toughness, etc) of hardened steel which occur when it is raised from a low to a higher temperature?

2.—All varieties of tool steel have been found to be capable, when suitably hardened, of producing double-peaked speed-durability curves (see Fig 1), the characteristics of such steels being that at a certain speed they are less durable than at either a [illegible] lower speed. Is it possible to correlate this low durabil[illegible] ed with a particular physical condition at a certain t[illegible]

3.—All tool steels are found to lose their durability when the cutting speed is raised above a certain limit. Is there any corresponding change in their physical properties when they are heated above a certain temperature?

4.—Assuming that each cutting speed corresponds to a definite temperature of the cutting edge (the weight of cut and all other conditions remaining constant), what are the actual temperatures of the cutting edge corresponding to the various cutting speeds, and corresponding to the various changes in the durability and physical properties of the steel?

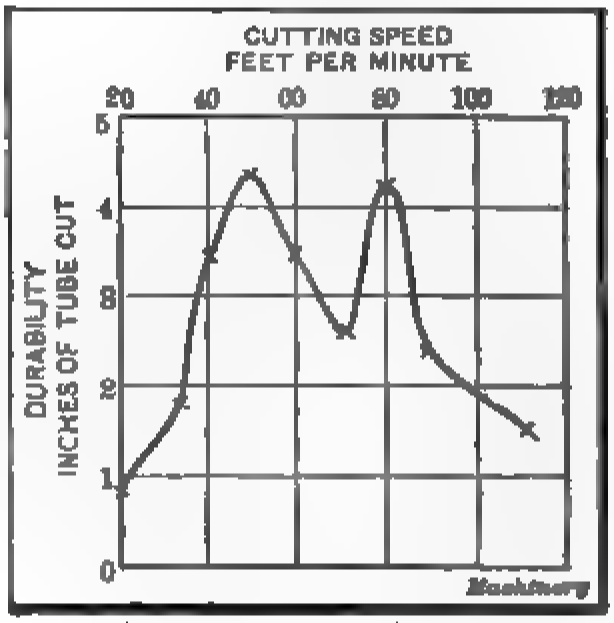

Fig. 1. Example of Double-peaked Durability Curve

Before dealing with these problems, it is necessary briefly to consider the nature of the actions tending to wear or blunt a cutting tool, and the correlative physical properties constituting durability, which the tool must possess in order to withstand these actions. The principal action to which a tool is subjected in cutting is one of friction under heavy pressure. This tends to rub away the surface of the steel, by causing the particles of steel to slide over one another. To resist blunting by this action a tool must possess hardness. But the stress on the tool point is not constant: as the chip is detached it breaks up into a series of short segments (more or less completely separated), and this process subjects the tool to a succession of changes of pressure, amounting almost to blows, and tending to chip off portions of the cutting edge. To withstand this action the tool must possess toughness.

If we make a tool of glass and another of copper, and use them to turn a cylinder of soft material, such as lead in the lathe, we shall find that both are very soon blunted, but from totally different causes. The glass tool, though extremely hard, is brittle, and is blunted by the chipping away of minute particles of the cutting edge. The copper tool, though very tough, is soft, and is blunted by the rubbing away of the cutting edge. If now we imagine that by some subtle alchemy we can gradually change the tool of glass into one of copper, it will probably pass through some intermediate stages where it will retain some of the hardness of glass without all its brittleness, and will have attained some of the toughness of copper without all its softness. The tool in this intermediate state will probably keep its sharp cutting edge much better than either the glass or the copper tool.

In order then to measure, throughout a range of temperatures, those physical properties of steel which constitute its durability, it is necessary to test it at each temperature for hardness and for toughness. Experiments with suitable apparatus were, therefore, carried out for

measuring the hardness and toughness at various temperatures, taking into consideration such factors as different methods of grinding the tools, etc. The experiments made it possible to answer the questions propounded above, as follows:

1.—The low durability of all tool steels, cutting under water at low speeds and light cuts, seems to be completely explained by the low values of hardness and toughness which always occur at cutting temperatures of 50 to 100 degrees C. (122 to 212 degrees F.). The breaking tests have shown in every case the product, hardness times toughness, increases in value as the temperature is raised above 100 degrees C. The cutting tests have shown in every case that the durability increases when the cutting speed is raised above 20 feet per minute. These cutting tests have also shown that the durability always increases when a tool working at 20 feet per minute is allowed to cut dry instead of with water, or with hot water instead of cold. It is impossible to doubt that these are different manifestations of the same physical change in the steel.

A clear recognition of this phenomenon is of great practical importance. A great deal of the metal cutting in every machine shop consists in taking fine finishing cuts, often with water on the tool. If such cuts are taken at a slow speed, the temperature of the cutting edge may not rise above 100 degrees C., in which case the tool will be quickly blunted. Its durability can be increased by increasing the speed or by cutting dry. Many cases are known to have occurred in ordinary workshop practice, where an increase in cutting speed has actually resulted in increased durability of the tool. Low durability at low cutting temperatures (on, for example, finishing cuts) is a familiar characteristic of high-speed steels, and is most marked in tools which have been suitably hardened for very high temperature work. High-speed steel can be so hardened as to retain its durability at fairly low temperatures, and there are now on the market tungsten steels specially adapted for low temperature work, such as finishing very heavy forgings; but every description of steel known to the author loses its durability if the cutting temperature is low enough. It should be noted that a low cutting temperature can only occur when there is a combination of low speed with light cut. A heavy or moderate cut raises the temperature of the cutting edge above 100 degrees C., even at very slow speeds.

2.—The phenomenon of the double-peaked curve is not completely elucidated, though the evidence goes some way to explain it. The variations of hardness and toughness with temperature are of a complicated character, and the cleft between the two peaks of a durability curve appears to be caused by the conjunction of depressions in the hardness and toughness curves at a particular temperature. The relative heights of the two peaks are found to vary with the conditions of cutting, and this variation may be due to a change in the relative importance of the hardness and toughness factors, according to the quality of the material cut, or the shape of the tool.

3.—The decline in durability which take[illegible] when a certain limit-

ing speed is exceeded, is evidently caused by an actual softening of the cutting edge by the heat generated in cutting. This softening, which is extremely local, takes place even when the tool and the work are practically immersed in running water. The speeds and temperatures at which the softening occurs depend largely on the particular hardening process which has been applied to the tool, and are generally highest in high-speed steel.

4.—It is not yet possible to establish an exact scale of cutting temperatures corresponding to the scale of cutting speeds, but a comparison of the temperature-durability tests with the speed-durability tests enables us to make an approximation, as in Fig. 2.

To establish the relation between the speeds of cutting with and without water, a comparison was made between the various results obtained in the tests, from which it appears that the effect of using water is approximately to double the cutting speed; in other words, the edge of a tool flooded with water attains about the same tempera-

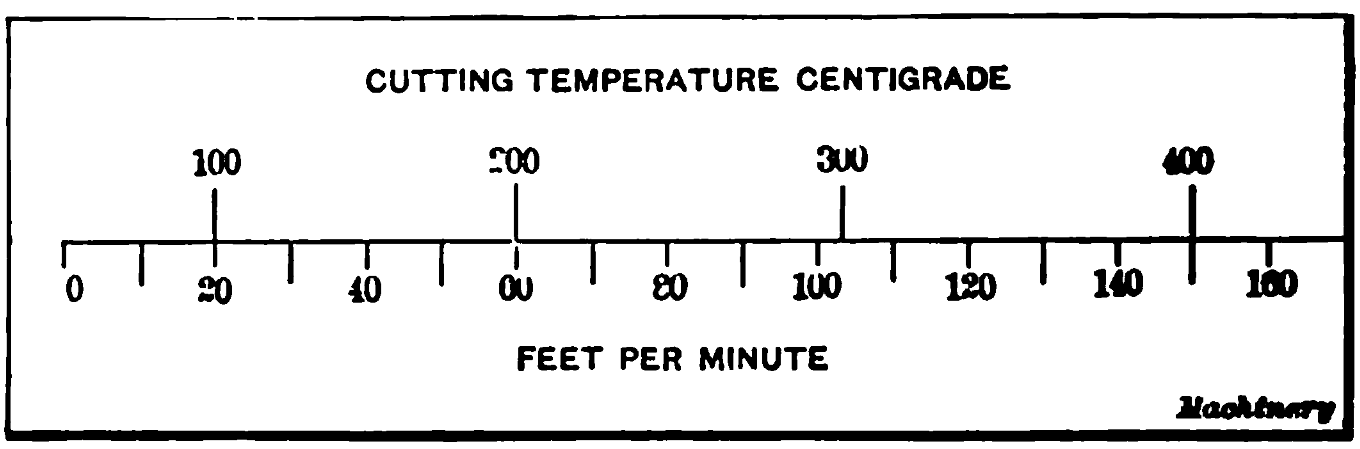

Fig. 2. Approximate Scale of Cutting Temperatures and Cutting Speeds when Testing in Tool Steel Testing Machine

ture as the edge of a tool cutting dry at half the speed. This must not be taken as a general statement applicable to all cutting operations. The dry cutting temperature depends largely on the volume of metal operated upon. The tube used in the tool steel testing machine is small in diameter and light in section; it becomes considerably heated under a dry cut. In machining a large forging, the body of metal absorbs a great deal of heat, with only a slight rise in temperature, and the use of water has less effect on the cutting speed.

Considerable interest attaches to a comparison of the durabilities of carbon and high-speed steels. It appears that the high-speed steel has two distinct features of superiority. The speeds at which it attains its maximum durability are not very different from those at which carbon steel is most durable, but the high-speed steel is several times as durable at these speeds. Quite distinct from its superior durability at moderate cutting temperatures is the property possessed by high-speed steel of retaining some durability at temperatures high enough to soften carbon steel, but its actual durability under such conditions is much less than under conditions which do not unduly heat it. In other words, its abrasive quality appears to be more important than its heat-resisting quality.

CHAPTER IV

DEVELOPMENT AND USE OF HIGH-SPEED STEEL

The following discussion on high-speed steel and tools made from this material is an abstract of a paper read by Mr. J M Gledhill before the Iron and Steel Institute of Great Britain The high-speed steels of the present day are combinations of iron and carbon with: (1) Tungsten and chromium, (2) Molybdenum and chromium, (3) Tungsten, molybdenum and chromium

Influence of Carbon

A number of tool steels were made by the Armstrong, Whitworth Co. with the carbon percentage varying from 0 4 per cent to 2 2 per cent, and the method of hardening was to heat the steel to the highest possible temperature without destroying the cutting edge, and then rapidly cooling in a strong air blast By this simple method of hardening it was found that the greatest cutting efficiency is obtained where the carbon ranges from 0.4 per cent to 0 9 per cent, and such steels are comparatively tough Higher percentages are not desirable because great difficulty is experienced in forging the steels, and the tools are inferior. With increasing carbon contents the steel is also very brittle, and has a tendency to break with unequal and intermittent cutting.

Influence of Chromium

Having thus found the best carbon content to range from 0 4 per cent to 0 9 per cent, the next experiments were made to ascertain the influence of chromium varying from 1 0 per cent to 6.0 per cent. Steels containing a low percentage are very tough, and perform excellent work on the softer varieties of steel and cast iron, but when tried on harder materials the results obtained were not so efficient With an increased content of chromium the nature of the steel becomes much harder, and greater cutting efficiency is obtained on hard materials. It was observed that with an increase of chromium there must be a decrease in carbon to obtain the best results for such a percentage of chromium

Mention may here be made of an interesting experiment to ascertain what effect would be produced in high-speed steel by substituting vanadium for chromium. The amount of vanadium present was 2 0 per cent The steel readily forged, worked very tough, and was hardened by heating to a white heat and cooling in an air blast This tool when tried on medium steel stood well, but not better than the steel with the much cheaper element of chromium in it

Influence of Tungsten

This important element is contained in by far the greater number [illegible]ent high-speed steels in use. A number of experiments

were made with the tungsten content ranging from 9.0 per cent to 27.0 per cent. From 9.0 per cent to 16.0 per cent the nature of the steel becomes very brittle, but at the same time the cutting efficiency is greatly increased, and about 16.0 per cent appeared to be the limit, as no better results were obtained by increasing the tungsten beyond this figure. Between 18.0 per cent and 27.0 per cent it was found that the nature of the steel altered somewhat, and instead of being brittle, it became softer and tougher, and while such tools have the property of cutting very cleanly, they do not stand up so well.

Influence of Molybdenum

The influence of this element at the present time is under investigation, and the experiments with it have so far produced excellent results; it has been found that where a large percentage of tungsten is necessary to make a high-speed steel, a considerably less percentage of molybdenum will suffice. A peculiarity of these molybdenum steels is that in order to obtain the greatest efficiency they do not require such a high temperature in hardening as do the tungsten steels, and if the temperature is increased above 1800 degrees F. the tools are inferior, and the life shortened.

Influence of Tungsten with Molybdenum

It was found that the presence of from 0.5 per cent to 3.0 per cent molybdenum in a high tungsten steel slightly increased the cutting efficiency, but the advantage gained is altogether out of proportion to the cost of the added molybdenum.

Influence of Silicon

A number of high-speed steels were made with silicon content varying from a trace up to 4.0 per cent. Silicon sensibly hardens such steels, and the cutting efficiency on hard materials is increased by additions up to 3.0 per cent. By increasing the silicon above 3.0 per cent, however, the cutting efficiency begins to decline. Various experiments were made with other metals as alloys, but the results obtained were not sufficiently good by comparison with the above to call for comment.

An analysis of one of the best qualities of high-speed steels produced by the author's firm (Armstrong, Whitworth Co.) is as follows: "A.W." Steel.—Carbon, 0.55 per cent; Chromium, 3.5 per cent; Tungsten, 13.5 per cent.

What may be said to determine a high-speed steel, as compared to an ordinary tool steel, is its capability of withstanding the higher temperatures produced by the greatly increased friction between the tool and the work due to the rapid cutting. An ordinary carbon steel containing, say, 1.20 per cent carbon, when heated slightly above the critical point and rapidly cooled by quenching in water, becomes intensely hard. Such a steel gradually loses this intense hardness as the temperature of friction reaches, say, 500 degrees F. The lower the temperature is maintained the longer will be

so that the cutting speed is very limited. With rapid cutting steels the temperature of friction may be greatly extended, even up to 1100 degrees F. or 1200 degrees F., and it has been proved by experience that the higher the temperature for hardening is raised above the critical point and then rapidly cooled, the higher will be the temperature of friction that the tool can withstand before sensibly losing its hardness. The high degree of heating (almost to the melting point, in fact) which is necessary for hardening high-speed steel, forms an interesting study in thermal treatment and is indeed a curious paradox, quite inverting all theory and practice previously existing. In the case of hardening ordinary carbon steels very rapid cooling is absolutely necessary, but with high-speed steels the rate of cooling may take a considerably longer period, the intensity of hardness being increased with the quicker rate of cooling.

Annealing High-speed Steel

Turning now to some points in the heat treatment of high-speed steel, one of the most important is the process of thoroughly annealing it after working into bars. Accurate annealing is of much value in bringing the steel to a state of molecular uniformity, thereby removing internal strains that may have arisen, due to casting and tilting, and at the same time annealing renders the steel sufficiently soft to enable it to be machined into any desired form for turning tools, milling cutters, drills, taps, threading dies, etc. Further advantage also results from careful annealing by minimizing risks of cracking when the steel has to be reheated for hardening. In cases of intricately-shaped milling tools having sharp square bottom recesses, fine edges, or delicate projections, and on which unequal expansion and contraction are liable to operate suddenly, annealing has a very beneficial effect toward reducing cracking to a minimum. Increased ductility is also imparted by annealing, and this is especially requisite in tools that have to encounter sudden shocks due to intermittent cutting, such as planing and slotting tools, or others suddenly meeting projections or irregularities on the work operated on. The annealing of high-speed steel is best carried out in muffle furnaces designed for heating by radiation only, a temperature of 1400 degrees F. being maintained from twelve to eighteen hours according to the section of the bars of steel dealt with.

A number of other methods are also used for annealing high-speed steel. The following method is recommended by one of the largest high-speed tool steel manufacturers in America. Particular attention is called to the temperatures to which the steel to be annealed is to be heated, the time necessary, and also, that powdered charcoal is given first, it having the preference over fine air-dried lime or powdered mica.

"In annealing high-speed steel, use an iron box or pipe of sufficient size to allow at least one-half inch of packing between the pieces of steel to be annealed and the sides of the box or pipe. (We call at- here to the fact that it is not necessary that each piece of

steel to be annealed be kept separate from every other piece, but only that the steel be prevented from touching the sides of the annealing pipe or box.) Pack carefully with powdered charcoal, fine dry lime or mica. Cover with cap, which should be air-tight, but if it is not, then lute on with fireclay. Heat slowly to a full red heat, about 1475 or 1500 degrees F., and hold at this heat from two to eight hours, depending on the size of the pieces to be annealed. A piece of 2 by 1 by 8 inches requires about three hours time. Cool as slowly as possible, and do not expose to the air until cold. A good way is to allow the box or pipe to remain in the furnace until cold."

A series of experiments were recently made to determine the proper temperature to which to heat high-speed steel for annealing. It was found then when this steel was heated to below 1250 degrees F. and slowly cooled, as in annealing, it retained the original hardness and brittleness imparted to the steel in forging. When heated to between 1250 and 1450 degrees F., the Brinnell test indicated that the steel was soft, but impact tests proved that the steel still retained its original brittleness. However, when heated to between 1475 and 1525 degrees F. the steel became very soft, it had a beautiful fine-grained fracture, and all of the initial brittleness had entirely disappeared.

In carrying these tests further, to 1600, 1750, and 1850 degrees F., it was found that the steel became very soft, but there was a gradual increase in brittleness and in the size of the grain, until at 1850 degrees F. the steel became again as brittle as unannealed steel; the fracture at this temperature was dull, dry and lifeless, and showed marked decarbonization. Dried air-slaked lime was used as a packing medium in making these tests. The steel was packed in tubes sealed air-tight on both ends. The decarbonization that took place was probably due to the oxygen in the air that had filled the intervening spaces between each minute particle of lime, before it was packed in the tube, attacking the carbon of the steel; this decarbonization would not have taken place if powdered charcoal had been used. The latter would have supplied all the carbon necessary to combine with any oxygen present in the tubes.

An annealing chart, taken by a Bristol recording pyrometer, showing the temperature of one of the annealing furnaces in which a well-known grade of high-speed steel is annealed by the manufacturer, is shown in Fig. 3. The method, which is carried on by this manufacturer day after day, is to first pack the bars to be annealed in ten-inch diameter wrought-iron pipes, about fourteen feet long, the packing medium being pulverized charcoal. Then both ends of the pipes are sealed air-tight with fireclay. The annealing furnaces are fired with coal and are brought up to 1500 degrees F. at 7 A. M. At this time the large furnace doors are opened and from four to six of the ten-inch pipes, previously packed with steel and sealed, are rolled into the furnace. The doors are then closed and the furnace is continuously fired until 5.30 P. M., the temperature being kept as near to 1500 degrees F. as possible. The chart, which shows two days will indicate how well this temperature has been maintained

5 30 P. M. firing is discontinued, all holes that might permit the influx of air are closed, and the pipes are permitted to cool down slowly with the furnace It will be seen, by again referring to the chart, that there is a gradual drop in temperature from the time firing is discontinued until the pipes are taken from the furnace the following morning preparatory to beginning another day's work.

The chart also indicates that the temperature of the annealed steel, when taken from the furnace, is about 1000 degrees F. This temperature is several hundred degrees below the critical point, or recales-

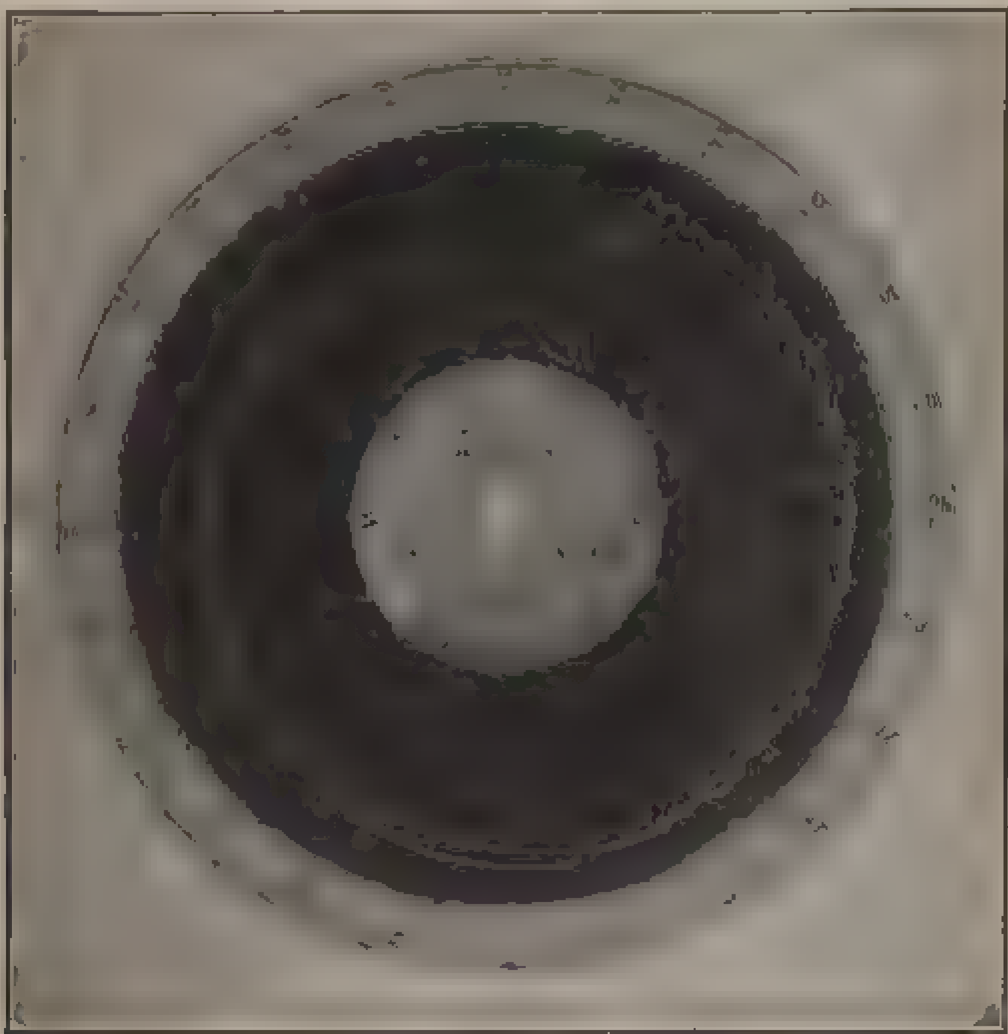

Fig. 3. Temperature Record obtained from an Annealing Furnace

cence point of high-speed steel, this point being at about 1350 degrees F., so that the annealed bars can be taken from the pipes and permitted to cool to normal temperature without further delay, because after cooling to 1000 degrees F. they would not again become hard without the application of more heat.

The above method is excellent for annealing high-speed steel on a large scale. If it is desired to anneal only a few small pieces of this grade of steel rapidly, they can be "water annealed," by a method similar to that used for carbon steels; the temperature to which the steel is raised, however, is not as high as for carbon steel. In water annealing, the piece to be annealed is gradually and uniformly heated to 760 degrees F It is then taken from the furnace and plunged into a bath of pure water, previously heated to a temperature of 150 de-

grees F., where it is permitted to cool until reduced to the temperature of the bath. Afterwards the steel can be drilled, filed, or machined into any form with little difficulty. The more care devoted to the heating, the better the results will be. To heat rapidly will induce internal strains and greatly increase the risk of breakage when the pieces are plunged into the water bath.

Another annealing method which differs considerably from those outlined on the preceding pages is used by a well-known tool manufacturer. While doubt has been expressed as to its practicability, it is claimed to give good results. There is only one objection; the pieces annealed will scale off somewhat, but as the surface is generally machined anyway, this objection is—for many classes of work—of no importance. The method is as follows:

Pack the tools to be annealed directly in the oven, one on top of the other, the furnace being entirely filled if necessary. Then heat the furnace to a temperature not exceeding 1700 or 1750 degrees F. It should not require more than three hours for the furnace to reach this heat, which is then maintained for about two hours more, or, until the temperature of all the tools has been raised to that of the furnace itself. (When smaller pieces are to be annealed, it is therefore, sufficient to maintain the heat for about one hour.) Then shut off the heat and at the same time close all holes, such as burner and draft holes, as carefully as possible, and let the tools cool off in the furnace. This cooling takes places very much quicker than when the first mentioned method is used, because the tools are not packed, and, hence, there is a saving in time not only in the heating but also in the cooling. The greater part of the expense of annealing is thus saved on account of the saving in fuel, and the elimination of the packing, packing materials and the boxes.

Forging and Hardening

In preparing high-speed steel ready for use the process may be divided principally into three stages: forging, hardening, and grinding. It is, of course, very desirable that high-speed steel should be capable of attaining its maximum efficiency and yet only require treatment of the simplest kind, so that an ordinarily skilled workman may easily deal with it, otherwise the preparation of tools becomes an expensive and costly matter, and materially reduces the advantages resulting from its use. Fortunately, the treatment of high-speed steel as produced by leading firms is of the simplest; simpler in fact than of ordinary carbon steels or of the old self-hardening steels. Great care has to be exercised in the heating of the latter steels, for if either are heated above a blood-red heat, say, 1600 degrees F., the danger of impairing their efficiency by burning is considerable; whereas with the high-speed steel, heating may be (and must be) carried to a much higher temperature, even to the melting point, it being practically impossible to injure it by burning. The steel may be raised to a yellow heat for forging, say, 1850 degrees F., at which temperature it is soft and easily worked into any desired form, the forging proceeding

until the temperature lowers to a good red heat, say, 1500 degrees F., when work on it should cease and the steel be reheated.

In heating a bar of high speed steel preparatory to forging (which heating is best done in a clear coke fire) it is essential that the bar be heated thoroughly and uniformly, so as to insure that the heat has penetrated to the center of the bar, for if the bar be not uniformly heated, leaving the center comparatively cold and stiff, while the outside is hot, the steel will not draw or spread out equally, and cracking will probably result. A wise rule in heating is to "hasten slowly."

It is not advisable to break pieces from the bar while cold, the effect of so doing tending to induce fine end cracks to develop which ultimately may extend and give trouble; but the pieces should be cut off while the bar is hot, then be reheated as before and forged to the shape required, after which the tool should be laid in a dry place until cold.

The temperature for hardening high-speed steel varies somewhat according to the class of tool being dealt with. When hardening turning, planing, or slotting tools, and others of similar class, only the point or nose of tool should be gradually raised to a white melting heat, though not necessarily melted, but no harm is done even if the point of the tool becomes to a greater or less extent fused or melted.

The tool should then be immediately placed in an air blast and cooled down, after which it only requires grinding and is then ready for use. Another method, which may be described, of preparing the tools is as follows: Forge the tools as before, and when quite cold grind to shape on a *dry* stone or *dry* emery wheel, an operation which may be done with the tool fixed in a rest and fed against the stone or emery wheel by a screw, no harm resulting from any heat developed at this stage. The tool then requires heating to a white heat, but just short of melting, and afterward complete cooling in the air blast. This method of first roughly grinding to shape also lends itself to cooling the tools in oil, which is specially efficient where the retention of a sharp edge is a desideratum, as in finishing tools, capstans and automatic lathe tools, brass-workers' tools, etc. In hardening where oil cooling is used, the tools should be first raised to a white heat, but without melting, and then cooled down either by air blast or in the open to a bright red heat, say, 1700 degrees F., when they should be instantly plunged into a bath of rape or whale oil, or a mixture of both.

Referring to the question of grinding tools, nothing has yet been found so good for high speed steels as the wet sandstone, and the tools ground thereon by hand pressure, but where it is desired to use emery wheels it is better to roughly grind the tools to shape on a dry emery wheel or dry stone *before* hardening. By so doing the tools require but little grinding after hardening, and only slight frictional heating occurs, but not sufficient to draw the temper in any way, and thus the cutting efficiency is not impaired. When the tools are ground on a wet emery wheel and undue pressure is applied, the heat generated by the great friction between the tool and the emery wheel causes the

steel to become hot, and water playing on the steel while in this heated condition tends to produce cracking.

With regard to the hardening and tempering of specially formed tools of high-speed steel, such as milling and gear cutters, twist drills, taps, threading dies, reamers, and other tools that do not permit of being ground to shape after hardening, and where any melting or fusing of the cutting edges must be prevented, the method of hardening is as follows:

A specially arranged muffle furnace heated either by gas or oil is employed, and consists of two chambers lined with fireclay, the gas

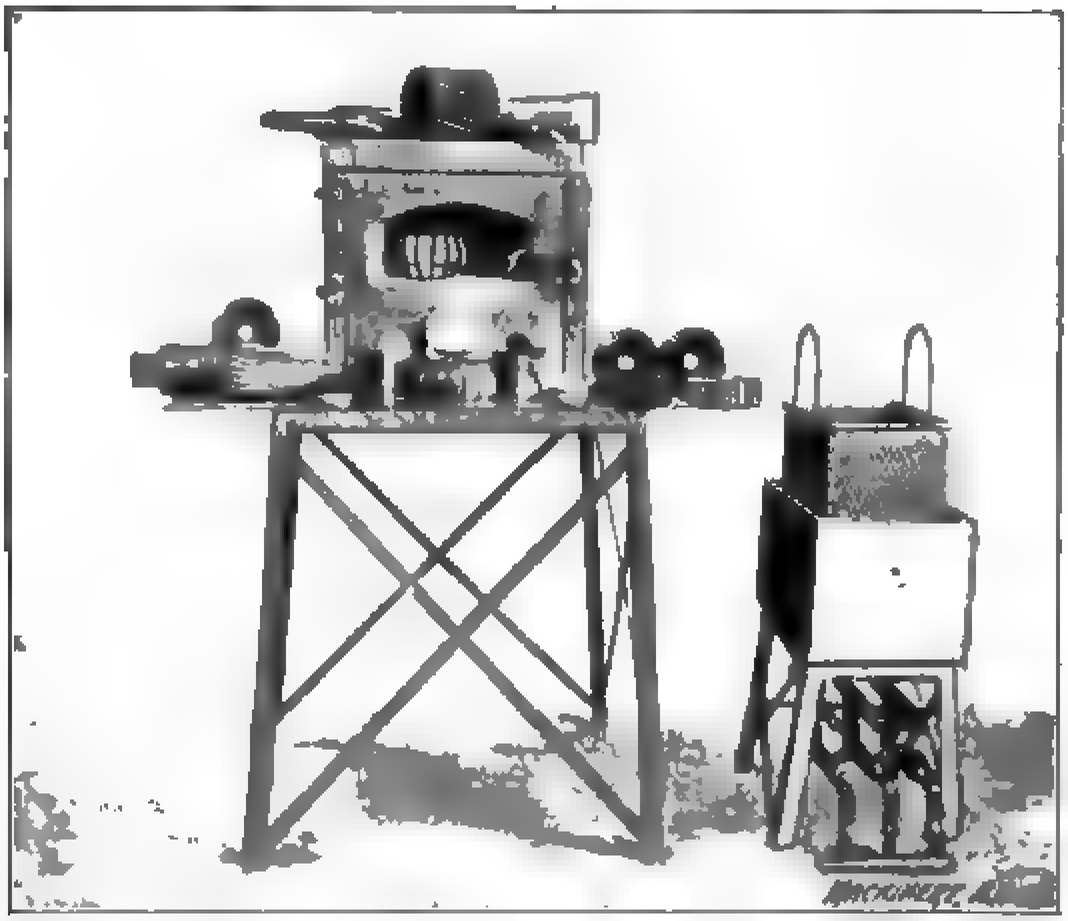

Fig. 4. Muffle Furnace for Hardening Milling Cutters made of High-speed Steel, also Tank and Dipping Cage for Tempering them in Oil

and air entering through a series of burners at the back of the furnace, and so under control that a temperature up to 2200 degrees F. may be steadily maintained in the lower chamber, while the upper chamber is kept at a much lower temperature. Before placing the cutters in the furnace it is advisable to fill up the hole and keyways with common fireclay to protect them. The cutters are first placed upon the top of the furnace until they are warmed through, after which they are placed in the upper chamber, Fig. 4, and thoroughly and uniformly heated to a temperature of about 1500 degrees F., or, say a medium red heat, when they are transferred into the lower chamber and allowed to remain therein until the cutter attains the same heat as the furnace itself, *viz.*, about 2200 degrees F., and the cutting edges reach a bright yellow heat, having an appearance of a glazed or greasy surface. The cutter should then be withdrawn while

the edges are sharp and uninjured, and revolved before an air blast until the red heat has passed away, and then while the cutter is still warm—that is, *just* permitting of its being handled—it should be plunged into a bath of tallow at about 200 degrees F. and the temperature of the tallow bath then raised to about 520 degrees F., on the attainment of which the cutter should be immediately withdrawn and plunged in cold oil.

Of course there are various other ways of tempering, a good method being by means of a specially arranged gas-and-air stove into which the articles to be tempered are placed, and the stove then heated up to a temperature of from 500 degrees F. to 600 degrees F., when the gas is shut off and the furnace with its contents allowed to slowly cool down.

Very satisfactory results in hardening high-speed steel tools, such as cutters, drills, etc., have been obtained by the following method: First pre-heat in an oven-type gas furnace to from 1300 to 1500 degrees F.; then transfer the steel to another gas furnace having a temperature varying from about 2000 to 2200 degrees F., when the steel has attained this temperature, quench in a metallic salt bath having a temperature varying from 600 to 1200 degrees F., depending upon the kind of high-speed steel used. The piece to be hardened should be stirred vigorously in the bath until it has obtained the temperature of the bath; then it is cooled, preferably in the air, and requires no further tempering; or it may be put directly into the tempering oil, which should be at a temperature anywhere between 100 and 600 degrees F. The tempering bath is then gradually raised to the heat required for tempering. The salt bath for quenching should consist of calcium chloride, sodium chloride and potassium ferro-cyanide, in proportions depending upon the required heat. Various kinds of steel require different temperatures for the metallic salt bath. After the temper of the tool has been drawn in the oil, the work is dipped in a tank of caustic soda, and then in hot water. This will remove all oil which might adhere to the tools, and is a method that applies to all tools after being tempered.

The Pyrometer and Time Study in Steel Treatment

The general experience of a maker of lathe and planer cutters for tool-holders, outlined briefly in the following, shows how necessary are exact scientific methods to insure the production of uniformly satisfactory high-speed steel tools:

"Investigations in machine shops and tool rooms indicate that the fault of most importance to the managers is the lack of uniformity in results obtained from high-speed cutting tools. Many places were found where attempts were made to treat steel by faulty methods or with inadquate facilities. The lack of pyrometers, failure to use pyrometers when provided, hardening in charcoal furnaces insufficiently heated and treating without pre-heating, were a few of the practices noted that produced ununiform results—a few good pieces and many almost worthless.

"It seems to be the general opinion among those not getting results that pyrometers are not of much use, that they do not give correct readings, and that better results can be gotten by depending on a man's experience than on any mechanical device. Now in the treatment of cutters we have had failures with pyrometers, but at the same time have found the cure for it, and that is frequent calibration. There is no question but what a man's eye is a better judge of the heat in a furnace than an incorrectly calibrated pyrometer.

"In the treatment of our cutters, we have probably employed no more skilled men than are used in many large plants for treating high-speed steel, but the methods that they use and depend on are scientifically correct. Since the adoption of the improved Taylor-White treatment of high-speed steel we have sent out thousands of cutters and have received practically no complaints. Our experience has shown that a cutter treated today is the same as one treated six months ago and will be the same as one treated six months from now. We have tested all makes of high-speed steel, and have proved that with proper heat-treatment any one of four or five of the real high-grade high-speed steels is entirely satisfactory and, in fact, cutters made from all of them cannot be told apart in use.

"All our cutters are pre-heated in a low-heated furnace at a temperature of 1350 degrees F. This heating takes out all strains in the metal and puts it in the best possible condition for bringing quickly to the high heat necessary to get the best results from high-speed steel. Every cutter from the smallest to the largest is treated in accordance with its sectional area and size. It goes from the low-heat into the high-heat furnace and stays there for a time that has been determined for each size of tests. We use pyrometers constantly on both furnaces, which are tested twice a week, having found that this is as long as they can safely go without being checked. The heat-treating room is provided with a specially made clock which starts on the pull of a lever by the man running the furnace, who knowing the proper length of time required for the cutter being treated, sets the clock accordingly. At the end of the predetermined time the clock rings a bell and stops, and the operator takes out a cutter and puts it into the proper medium.

"Our experience shows that it is necessary to bring the high-heat furnace to a temperature above the melting point of high-speed steel to get satisfactory results. This, of course, requires positive accuracy of the time chart as a fraction of a minute too much in the furnace would ruin the cutter, and too short a time would not give sufficient heat. Another reason for this is that to get the best results from high-speed steel, it is necessary to quickly raise the heat from 1350 degrees F. to the highest heat required.

"We believe that the essentials for proper treatment of high-speed steel are: a first-class quality of high-speed steel, pre-heating, quickly raising the temperature of the steel to the proper
a high-heat furnace, the use of accurately calibrat
a correct time chart."

Hardness or Temper of High-speed Steel Tools

Of the elements involved in tool efficiency, hardness or temper formerly was considered the most important, the design and conditions of use being little regarded. At the present time, the intelligent making of high-speed tools involves a consideration of all these and other elements, relegating to hardness or temper its appropriate place. The extreme hardness of many of these tools has frequently led to the inference that a tool has been properly treated if it is very hard, so hard that a good file will not "touch" it However, extreme hardness is not always an indication of the efficiency of a high-speed tool; although it is necessary in certain classes of work (cutting refractory stock, for instance), in others it not only is unnecessary, but perhaps even undesirable. As a matter of fact the largest users of the best makes of high-speed steel find that for many purposes tools do the best work and give the most efficient service when soft enough to be "touched" by a good file, and even when so soft that it will "take hold." However that may be, the file test for high-speed tools is quite valueless even in those cases where it is desirable that the degree of hardness be determined Such tests, to be of value, would require that the files must be absolutely uniform in temper. Even the best of files, however, vary more or less in temper and hardness, and a tool passed as "hard enough," when tested by one file might easily fail to pass the test when tried by another, presumably of the same temper.

Disadvantages of High-speed Steel Tool-holders

The early method of economizing in steel by using tool holder stock rather than making the entire tool of high speed steel, in the case of those tools whose cutting edges or points work without intermission (as those used for turning, planing and similar operations) is open to criticism, and is not now so generally followed as formerly A characteristic of the operation of high-speed tools is the rapid generation of heat in the cutting edge. In the case of milling cutters and kindred tools this is of small consequence, because the cutters are intimately attached to a relatively large mass of metal which conducts the heat away very efficiently. Furthermore, these cutters work intermittently, each for a very brief space of time, and for the remainder of the revolution are exposed to the air and cooled by it. The cutting edges are not allowed, therefore, to get exceedingly hot, as is the case with the edge of a turning tool run at the same speed. It is necessary that the body of such a turning (or similar) tool be large enough to conduct away a considerable portion of the heat generated at the cutting edge; and in order to do this effectively the tool must be continuous; that is, there must be no appreciable separation between the part of the tool which does the cutting and the body from which most of the heat radiates, as there is ordinarily when a small steel is held in a tool-holder. There are tool-holders which his difficulty, and which are satisfactory in smaller sizes.

Methods of Uniting High-speed Steel with the Tool Body

From the very first, methods were sought whereby high-speed steel cutting points could be intimately combined with tool bodies made of ordinary and much cheaper steels. For the most part the methods tried were ineffective and impracticable. The reasons are not well understood. The disinclination of the two steels to unite probably is due to a difference in their coefficients of expansion. There is, however, no trouble in brazing them together; and when this does not involve placing a great strain upon the brazed joint, this method does very well. Obviously the cutters âre hardened before being brazed into place. A successful example of such a combination is a lathe or a planer tool made with practically no forging and with a relatively thin plate of high-speed steel brazed to the front and top to form the cutting edge. Rose and other forms of reamers and mills have been made in a similar way, the body of machinery steel being machined with recesses for high-speed blades, which are brazed into place. Such tools have been in use for several years, with satisfaction. The latter, especially, are as good as if of solid high-speed steel except when it is essential that they be re-annealed or re-hardened—which is seldom necessary.

Almost as soon as the new steels made their appearance, the feasibility of welding, electrically and autogenously, a high-speed cutting point and a machinery steel tool body was demonstrated. Such tools conform to the requirement of being perfectly continuous, and the weld is practically as strong as the rest of the tool. It is feasible to forge the end to any required shape as if the entire tool were of high-speed steel; and, since in hardening only the nose is heated to a high heat, the machinery or tool steel body is in nowise impaired. The method of electrical welding, as used in this connection, is exceedingly simple. The two pieces to be welded are attached to the terminals of a circuit of suitable voltage, and the edges brought together. The resistance to the passage of the current offered by the imperfect contact sets up enough heat to melt the metal and forms a perfectly homogeneous junction. The autogenous (oxygen and acetylene blowpipe) method is almost as simple; the flame is directed into the crevice where the two pieces are brought together, and melts the adjacent metal so as also to form a homogeneous joint.

Fig. 5 shows samples of electric welding which are of special interest to machine shop managers, foremen, and others interested in economical shop practice. They illustrate the economy in the use of high-speed steel, made possible by the electric welding process. The upper left-hand figures show a counterbore made with a carbon steel shank and high-speed cutting part electrically welded thereto. Below these views are views of a lathe center with carbon steel shank and high-speed steel tip, before and after finishing. In the same illustration are shown diamond point, side and turning lathe tools of high-speed steel welded onto carbon steel or machine steel shanks.

A twist drill broken in the shank can be repaired by welding on a

new piece, and with high-speed twist drills, the saving in expense is considerable. The process is also advantageous in making extension drills. The ordinary practice is to weld on a wrought-iron shank or to insert a wrought-iron filling piece, because of the difficulty of making welds in steel. The electric welding process makes it possible to weld on carbon steel shanks which, of course, are stiffer and stronger than wrought iron. The figure directly below the lathe tools shows a twist drill with a repaired tang, the tang having been twisted off and replaced by another tang electrically welded.

A method for welding high-speed steel cutters to machine steel bodies or shanks has been patented by Mr. Paul A. Viallon, 102 Avenue

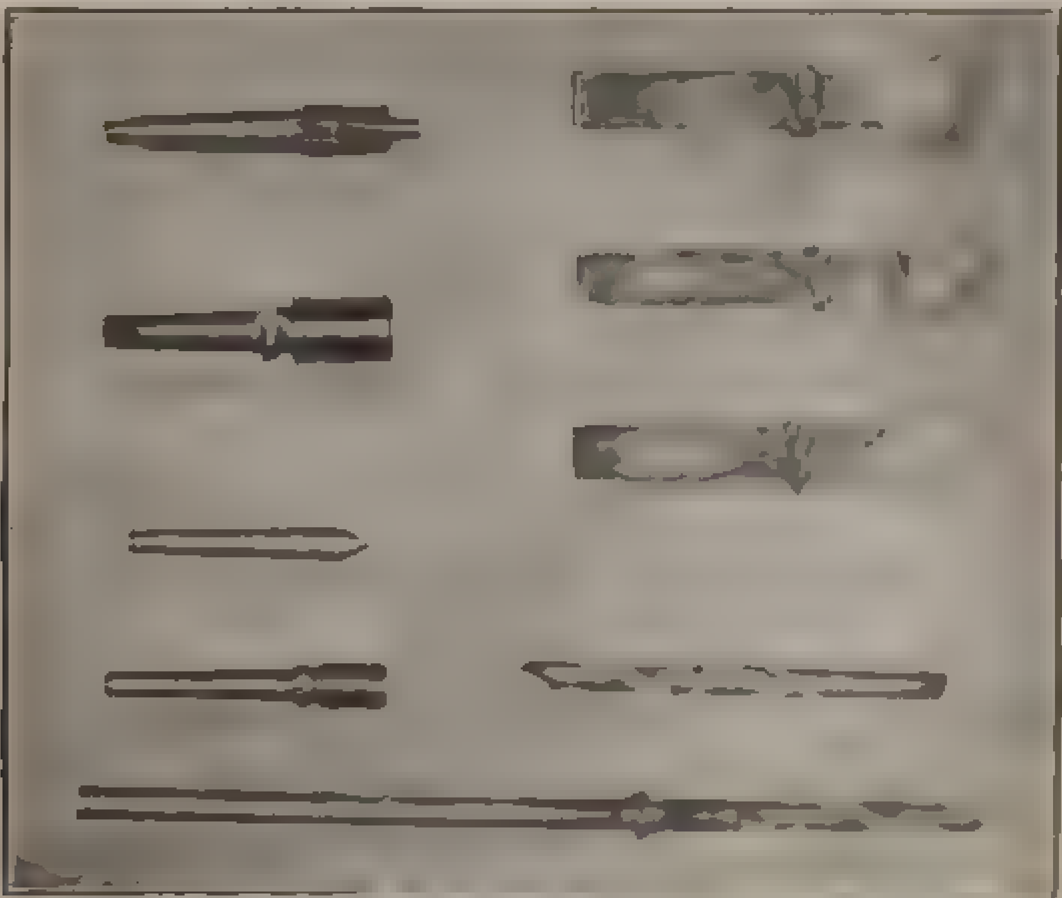

Fig. 5. [illegible]

Parmentier, Paris, France. [illegible] and inexpensive. The [illegible] A in Fig. 6, and the [illegible] shown at B. The [illegible] and the cutter [illegible] placed on the [illegible] are [illegible] of [illegible] the cutter and the [illegible] to the [illegible] the [illegible] and [illegible]

steel, and hardened. When the welded-on part of high-speed steel is worn down so that it must be replaced by a new cutter, the old cutter may be detached without injuring the machine steel shank, by heating the cutter and the shank at the joint, and then removing the cutter by pressure applied on its side.

Another method (patented) recently brought forward, somewhat resembling brazing, is asserted to give a joint fully as strong as the rest of the tool. A thin film of copper is placed along the line of the joint, and the parts to be welded are surrounded by a reducing compound and then placed in a furnace raised to a temperature of about 1200 degrees C. (2200 degrees F.). The copper flows freely into the interstices and is said to produce actual cohesion between the adjacent molecules, making a perfect joint, so strong that a fracture will follow a new break rather than pass through the joint.

These methods are available for all classes of tools made partly of high-speed and partly of machinery steel or other materials. Reamer and mill blades, die faces, shear blades, jack knives, etc., all are readily welded to supporting forms or backs and make tools quite as

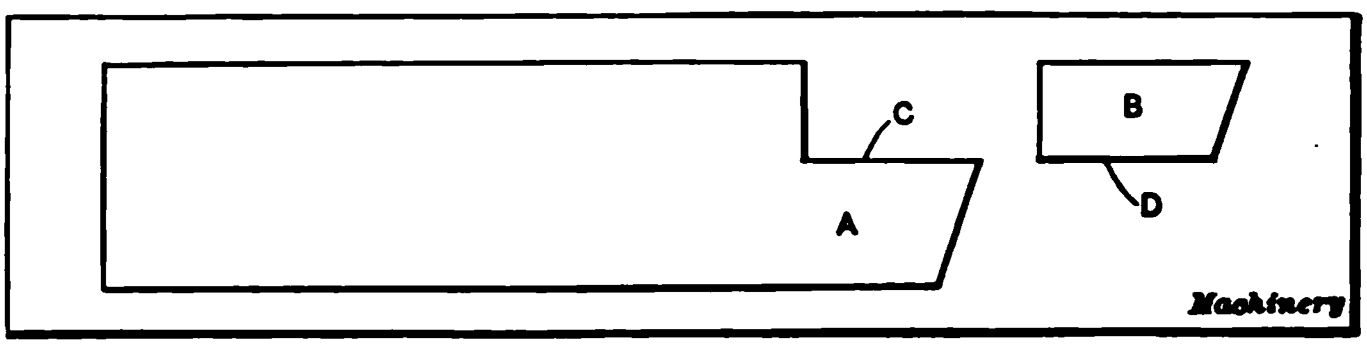

Fig. 6. High-speed Steel Cutter to be Welded to Shank of Machine Steel

efficient as if of solid high-speed steel—and generally much more so than if the cutters or faces were attached by screws, bolts, rivets, or similar methods. Long-shank and extension drills, reamers, etc., can readily be made with the cutting parts of high-speed steel and the shanks of cheaper steel. The processes mentioned, especially the electrical, are available also for the repair of broken tools, many of which can thus be saved for further use. The repairing may involve the welding of the broken parts or the replacing of an old part by a new, as may be most expedient.

Cutting High-speed Steel

Only an expert can nick and break high-speed steel from the bar without damage to the structure adjacent to the fracture—and even an expert cannot be sure of doing so with safety; the best way, where the end is to be used for working purposes, is to cut the bar. The circular saw most frequently used does very well, though a band saw works better and rather more rapidly. Small bars can readily be cut in bundles, if held very rigidly. The saws, obviously, should, themselves, be of high-speed steel. Complaints have been made that it is impossible to saw these steels. The complaints probably originated in the use of improperly hardened saws; for there is no difficulty whatever in cutting them with suitable saws. A singular but most

effective method has been employed to some extent. It consists in the use of a highly-speeded disk of tough steel. When an unused disk is first forced against the high-speed steel, the disk does not take hold well; but after being run in contact with the high-speed steel for a time it cuts perfectly and rapidly, leaving a clean burrless kerf. The disk may be of any steel tough enough to withstand the tremendous centrifugal (and other) stresses set up by the pressure and the terrific speed required. Just why such a disk cuts is not exactly clear The periphery is usually found studded with particles of the steel being cut, and the "sawdust" appears to be the result of true cutting.

Detecting Cracks in High-speed Steel Tools

Fine cracks in tools are most difficult to discover Even the microscope often fails to disclose them Generally they can be detected, if present, by the very simple expedient of moistening the suspected surface with petroleum, rubbing clean, and then wiping off with chalk. Some petroleum enters the cracks and afterwards sweats out, moistening the overlying chalk The nature and extent of the cracks are thus rendered visible. This frequently is of great importance in testing lots of high-speed steel tools.

Re-forging of Worn-down Tools

Tools which have worn down so as to be useless can usually, when made of solid high-speed steel, be forged or machined down and worked into tools of smaller size, if care is exercised. It is necessary always to re-anneal prior to attempting to machine such old tools; and it is also expedient when forging them to smaller shapes. In passing, it might be mentioned that re-annealing is desirable after machining and before hardening all sorts of intricately-shaped tools, in order to relieve any possible machine-caused strains In re-forging high-speed tools, whether for reduction in size or merely in re-fettling, it is desirable that they be heated rather slowly at first; they should not be thrust cold into a very hot fire.

Some Results of the Use of High-speed Steel

That great economy is effected by the use of high-speed steel is beyond all doubt, from whichever point of view the question is looked at; for it is not only rapidity of cutting that counts, but the output of machines is correspondingly increased, so that a greater production is obtained from a given installation than was possible when cutting at low speeds with the old tool steel, and the work is naturally produced at a correspondingly lower cost, and of course, it follows from this that in laying down new plant and machines the introduction and use of high-speed steel would have considerable influence in reducing expenditure on capital account. It has also been proved that high-speed cutting is economical from a mechanical standpoint and that a given horse-power will remove a greater quantity of metal at a high speed than at a low speed, for although more pow
ally required to take off metal at a high than at a lo

reason of the increased work done) the increase of that power is by no means in proportion to the large extra amount of work done by the high-speed cutting, for the frictional and other losses do not increase in anything like the same ratio as a high-cutting speed is to a low-cutting speed. A brief example of this may be given in which the power absorbed in the lathe was accurately measured, electrically.

Cutting on hard steel, with 3/16 inch depth of cut, 1/16 inch feed, and speed of cutting 17 feet per minute, a power of 5.16 horsepower was absorbed, and increasing the cutting speed to 42 feet per minute, the depth of cut and feed being the same, there was a saving in power of 19 per cent for the work being done. Another experiment with depth of cut 3/8 inch and traverse 1/16 inch compared with 1/16 inch traverse and 3/16 inch depth of cut, showed a saving in power of as much as 28 per cent, and still proceeding with a view of increasing the weight of metal removed in a given time the feed was doubled (other conditions being the same) and a still further saving of power resulted. In a word, as in the majority of things, so it is with rapid cutting, the more quickly work can be produced the cheaper the cost of production will be.

Again, as regards economy, there is not only a saving effected in the actual machine work, but since the advent of high-speed cutting it is now possible, in many instances, to produce finished articles from plain rolled bars, instead of following the old practice of first making expensive forgings and afterward finishing them in the machine. By this practice not only is the entire cost of forging abolished, but the machining on the rolled bar can be carried out much quicker and cheaper in suitably arranged machines, quicker even that the machining of a forging can be done.

Example of Efficiency of High-speed Steel

A remarkable example of the gain resulting from the use of high-speed tools may be recorded; the articles in this case being securing-bolts, made by the author's firm, for armor plates. Formerly where forgings were first made and then machined with ordinary self-hardening steel, a production of eight bolts per day of ten hours was usual. With the introduction of high-speed steel, forty similar bolts from the rolled bar are now produced in the same time, thus giving an advantage of five to one in favor of quick cutting, and also in addition abolishing the cost of first rough-forging the bolt to form; in fact, the cost of forging one bolt alone amounted to more than the present cost of producing to required form twelve such bolts by high-speed machining. The cutting speed at which these bolts are turned is 160 feet per minute, the depth of cut and feed being respectively ¾ inch and 1/32 inch, the weight of metal removed from each bolt being 62 pounds, or 2480 pounds in a day of ten hours, the tool being only ground once during such period of work; from such an example as this it will be at once apparent what an enormous saving in plant and cost results.

Equally remarkable results are obtained with high-speed milling cutters, and one example among many may be cited. Hexagon nuts for 3⅜-inch diameter bolts are made from rolled bars, the cutting speed of milling being 150 feet per minute, giving a production of ninety nuts per day, against thirty formerly. More than ninety nuts could have been produced had the machine been more powerful.

The Newer High-speed Steels

After the metal cutting industries had taken breath, so to speak, following the advent of air-hardening or high-speed steels, and begun to adjust themselves to the new situation, the use of self-hardening or mushet steels rapidly decreased until very little call for it existed and most manufacturers ceased making it altogether, putting out instead a more or less excellent quality of the high-speed kind. This, however, was not for some little time after the Taylor-White discoveries became public. The self-hardening steels had come into rather general use in difficult jobs, and in progressively managed shops were used to a considerable extent on all sorts of jobs; and so, while the new steels with their wonderful possibilities were justifying themselves and establishing their place, very properly there was a disposition to hold fast to that which had already proved itself, rather than to take up something but little known or tried.

Recently there has again come to be some demand for steels which, while possessing the qualities of high-speed steel to a moderate degree, enough to adapt them to a class of work not requiring its high cutting powers and red-hardness, could be bought at a price considerably below that of high-grade air-hardening steel; and a number of manufacturers have brought forward steels to fill this gap. There doubtless are many kinds of work wherein a steel of less endurance than the best high-speed varieties would answer every requirement and yield results equally as good—jobs where extremely high speeds or heavy cuts are in the nature of the case impracticable, or as in certain wood-working operations, where a cutter of higher endurance than one of the best carbon steel would have an almost indefinite life anyway. In such cases, it would seem, the high cost of air-hardening steel imposes an unnecessary expense in tool equipment.

Most such "new" steels are nothing more nor less than mushet or self-hardening, though some seem to be manganese rather than tungsten steels. A typical example of such a "special," "intermediate," or "semi-high-speed" steel, of excellent sustaining power and not exceptionally hard to treat, has the composition:

Carbon	1.19	per cent.
Tungsten	7.56	per cent.
Chromium	3.34	per cent.
Manganese	0.46	per cent.
Phosphorus	0.024	per cent.
Sulphur	0.025	per cer
Silicon	0.20	per c

Another, corresponding still more closely in its composition to mushet steel, gave this analysis:

Carbon	0.94 per cent.
Tungsten	4.78 per cent.
Chromium	0.69 per cent.
Manganese	0.27 per cent.
Phosphorus	0.01 per cent.
Sulphur	0.01 per cent.
Silicon	0.11 per cent.

Both these steels, it will be observed, are rather lower in carbon than most mushet steels formerly were, and the first is rather higher in tungsten while the second is lower in chromium. A third, which scarcely falls within the mushet class, is thus composed:

Carbon	1.25 per cent.
Tungsten	2.25 per cent.
Chromium	0.28 per cent.
Manganese	0.85 per cent.
Silicon	0.21 per cent.

The latter is advertised and sold specifically as a "finishing" steel; and it unquestionably gives excellent results in this particular kind of work. There are, besides, a number of other steels on the market, sold for tool use, the tungsten contents (or molybdenum equivalent) of which ranges anywhere below that essential to a high-grade high-speed steel—say 17 per cent—and down to that indicated in the analysis above. Most of these are sold as high-speed steels, though usually at a lower price than is customary for those of highest grade, and to a greater or less extent are so, when the chromium content corresponds with the tungsten.

Still another steel very widely advertised as an "intermediate" steel, and certainly working exceedingly well in certain classes of work, including blanking and stamping as well as cutting wood and metals of moderate hardness, has this anomalous composition:

Carbon	1.03 per cent.
Tungsten	0.46 per cent.
Manganese	0.30 per cent.
Phosphorus	0.025 per cent.
Sulphur	0.009 per cent.
Silicon	0.008 per cent.

This is represented as a very dense steel requiring very slow and careful heating to a bright cherry-red (800 to 850 degrees C. or about 1500 to 1550 degrees F.) for cutting tools, and somewhat lower for tools intended to withstand pressure or blows. It is water hardening, as might be supposed from its composition, and requires the temper to be drawn, as in the case of carbon steel tools. It is claimed to be at least 50 per cent tougher than carbon tool steel—though that is about what it seems really to be except for being high in manganese. Several other steels sold for about the same purposes also have about the same amount of manganese, and some a certain amount higher.

CHAPTER V

HARDENING AND TEMPERING STEEL

While there have been many articles published regarding the hardening and tempering of steel and the furnaces used, there is but little detailed information available regarding the baths used for these operations. The time has long since passed when each hardener had his own carefully guarded secrets regarding the composition of quenching baths. On the other hand, the time has also passed when it was a common belief that to harden a piece of steel it was only necessary to cool it off more or less rapidly in almost any kind of cooling medium; it has been found that the cooling mediums for hardening and the heating mediums or baths for tempering do, after all, play quite an important part both as regards economy and the efficiency of the tools treated. It is the intention in this article to outline the methods which have proved most successful, and to give the compositions of baths which from long experience in connection with hardening operations have proved to give the best all around results and to be the most economical; in many cases they have not been the cheapest in initial cost, but nevertheless are most economical because of the better results obtained with the tools treated and the greater length of time that the baths could be used before deteriorating. A description of such receptacles—cooling tanks and tempering furnaces—for the treatment of steel as have proved to be the best for all around purposes has also been included

For the sake of convenience the subject to be treated will be divided into four distinct parts as follows: (1) Baths used for cooling (quenching). (2) Baths used for tempering (drawing the temper after hardening). (3) Some tests and analysis of baths referred to under (1) and (2). (4) Receptacles and furnaces used in quenching and tempering.

Characteristics of Quenching Baths

No matter what the composition of a quenching bath, to insure uniform hardening the temperature of the bath must be kept constant, so that successive pieces of steel or tools quenched will be acted upon by baths of the same heat. The necessity of a uniform temperature for a quenching bath will be readily understood by reference to ordinary water for a cooling bath; everyone having any knowledge of the subject knows that a tool quenched in such a bath at room temperature will come out much harder than if quenched when the water is at the boiling point. In fact, it is well known that one way of partially annealing steel is by plunging it at a red heat into hot water The same difference in hardness will result when using any quenching bath at different temperatures, and hence no actual and dependable data can be obtained unless means are taken for keeping these baths at a uniform heat.

When using quenching baths of different composition the tools quenched will vary in hardness. This is due mainly to the difference in heat-dissipating power of the different baths. Thus a tool hardened at the same temperature in water and brine will come out harder when quenched in brine; the greater the conductivity of the bath the quicker the cooling. The general opinion, today, is that the composition of a quenching bath is of small importance as long as the bath cools the pieces rapidly. Those who have made a study of the subject have found different opinions regarding the same quenching bath by different users, and a good many quenching fluids have been condemned owing to improper heating and in many cases to improperly built furnaces.. As an example may be cited an oven furnace with which the user once had trouble. Owing to faulty construction of this furnace, more air was let into the heating chamber of the furnace than could be taken care of by the fuel oil; after having condemned first the steel and then the quenching bath, and then trying one quenching bath after another with the same results, it was suggested that the "heating" did not look just right, and an expert was called in to find out what the trouble was. After much experimenting with the burners and the furnace itself good results were finally obtained. The difficulty seemed to be that the oxygen of the air attacked the steel and formed oxide of iron on the surface of the tools, which consequently had a soft scale on the outside.

Those who are skeptical as to there being any difference in the effect on steel of cooling baths of different composition will readily admit that it is advantageous to use baths free from oxygen and from ingredients that tend to oxidize. Quenching baths should be uniform; good tool steels of high carbon are very sensitive to differences in both water and oils. Water for hardening tool steel should be soft; entirely different and very unsatisfactory results will be obtained when using hard water. While different quenching oils show less difference in the results obtained, vegetable and animal oils will give somewhat different degrees of hardness depending upon the sources from which they are obtained. One cannot be too careful in the selection of water, as it is likely to contain many impurities. If it contains greasy matters, it may not harden steel at all, whereas if it contains certain acids, it will be likely to make the tools quenched in it brittle and even crack them.

List of Quenching Baths

(1) Water—soft—preferably distilled; good tool steel should require no mixture added to pure water. (2) Salt added to water; will produce a harder "scale" than if quenched in plain water. (3) Sea (salt) water—the keenest natural water for hardening. (4) Water as under (1), containing soap. (5) Sweet milk.* (6) Mercury.* (7) Carbonate of lime.* (8) Wax.* (9) Tallow.* (10) Air—mostly used for high-speed steel; mere exposure, however, is in many cases and on many steels not sufficient to produce hardness and an air blast is necessary, as this furnishes cool air in rapid motion. (11) Oils such

* Generally used for special purposes only.

as cottonseed, linseed, whale, fish, lard, lard and paraffine mixed, special quenching oils, etc.

The following list of oils and names of firms supplying them is given for the sake of convenience. The firms mentioned are reliable and their oils have been thoroughly tried out in comparison with other makes and have proved to be superior; opinions may, of course, differ in this respect and no doubt there are many oils that have not been tried that may be as good.

Cottonseed oil—Union Oil Co., Providence, R. I.; Underhay Oil Co., Boston, Mass.

Linseed oil—Spencer Kellogg & Sons, Inc., Buffalo, N. Y.

Whale oil—no difference found between two different kinds.

Fish oil—only one kind tried.

Lard oil—W. B. Bleecker, Albany, N. Y.; E. F. Houghton & Co., Pittsburg, Pa.

Paraffine oil—Underhay Oil Co., Boston, Mass.

Special quenching oil—E. F. Houghton & Co., Pittsburg, Pa. Very good and cheap. While this may possibly deteriorate somewhat faster than some of the others mentioned it will prove very economical.

The order of the intensity with which various cooling baths will harden steel of about 0.90 to 1.00 per cent carbon is as follows: Mercury, carbonate of lime, pure water, water containing soap, sweet milk, different kinds of oils, tallow and wax. In all cases, except possibly the oils, tallow and wax, it must be remembered that the tools become harder as the temperature of the bath becomes lower.

Baths used for Tempering

The object of tempering is to reduce the hardness and to remove internal strains caused by sudden cooling in quenching. The composition of a tempering bath is of little importance compared with that of a quenching bath when considering the effect upon the pieces treated. Aside from the operator's convenience and possible bad effects upon his health, the different baths used for this operation must be considered with regard to initial cost, lasting quality, effects on finish, etc.

While oil is the most widely used medium for tempering tools in quantities, other means and methods are employed, especially by those who have tools in small quantities to temper, when the expense of installing and running an oil tempering furnace would not be warranted. Of these methods we first find the one used by the old-style tool hardener of only partly cooling the tool when quenching it, then quickly withdrawing it, polishing off the working surface, and then letting the heat which remains in the tool produce the required temper as judged by the color. If the tool has a shank, it is good practice to heat part of the shank also and quench the working part of the tool only, in which case this part can be cooled off thoroughly; the heat remaining in the body or shank of the tool will do the tempering, which also in this case must be judged by the color.

The sand bath is another frequently used medium for tempering, the sand being deposited on an iron plate and heated; by the use of this

method a piece to be tempered can be given different tempers throughout its length, as, for example, rivet hole punches; these are placed endwise—bottom down—in the sand about two-thirds projecting outside the sand into the air (see Fig. 7). It is readily seen that the nearer the bottom of the sand bath, the higher the heat, and the punch so placed, when tempered right, will have the bottom soft—a deep dark blue—the neck a very dark straw, and the working part of the punch on top a

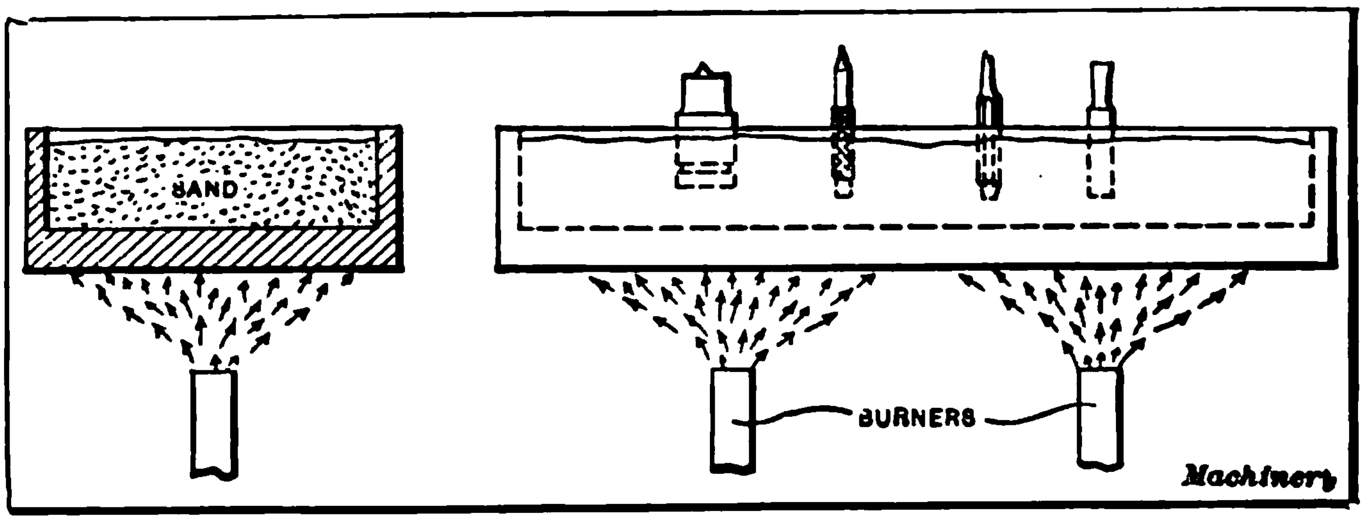

Fig. 7. Arrangement used for Sand Tempering

light straw color; thus there is a gradual increase in hardness from the bottom up. Pieces so drawn must previously have been polished, and the temper is judged by the color. When the pieces have attained the right color they are, of course, cooled off, generally in water or oil. A plate without sand similarly heated can also be used, but it is not as satisfactory.

A plate arranged as shown in Fig. 8 will be found very convenient when drawing small, round pieces. The pieces are rolled on the in-

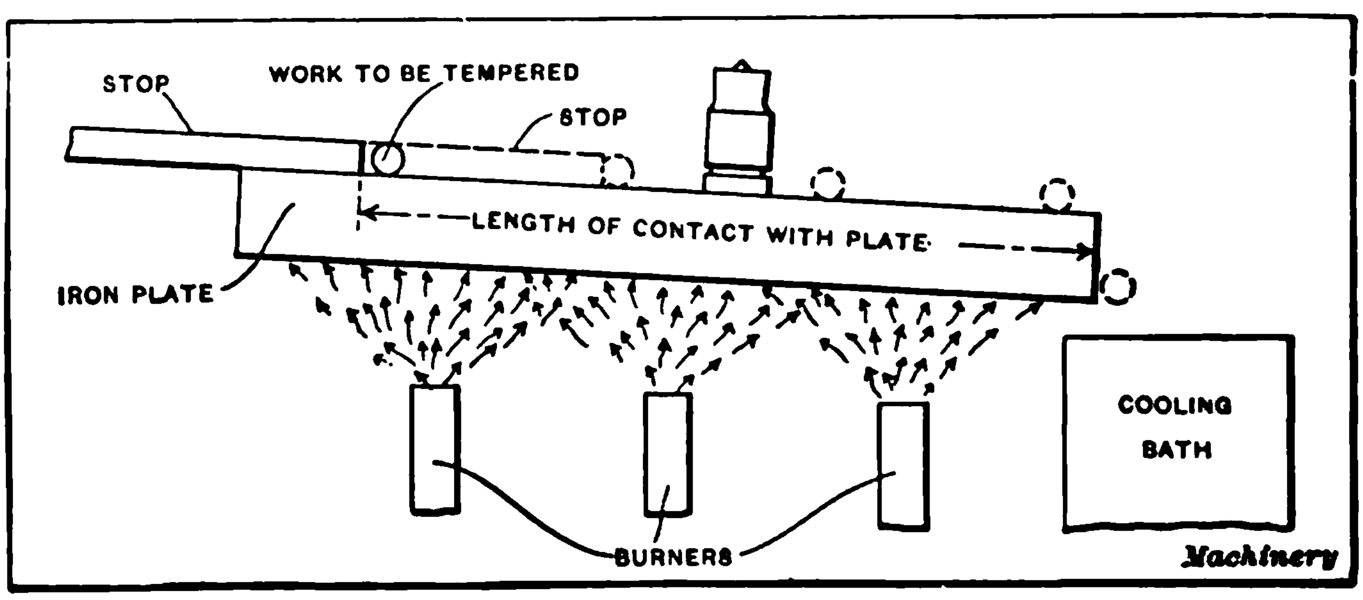

Fig. 8. Tempering Arrangement utilizing an Inclined Plate on which the Objects roll down

clined plate which is heated as indicated. The length of time the work is in contact with the plate can be regulated by adjusting the amount of the incline, as well as the location of the "stop." This arrangement can also be used for such work as punches, etc., in which case the plate, of course, should stand level and not in an inclined position.

Another frequently used tempering medium is hot air, the temper in this case also being judged by the color. For this method of tempering special furnaces should be employed in order to get uniform re-

sults. This method is used more especially for small and light work in quantities and where the color has to be bright and clear. While all of these methods have the advantage of enabling one to actually see the temper given to tools treated, the oil tempering bath is the one mostly used owing to its economy.

The two main points to be considered when using an oil tempering furnace are: first, to have the heat uniform throughout (not hotter where the burners or flames are in contact with the walls of the furnace); and second, to leave the pieces to be tempered in the oil long enough to have attained the heat of the oil throughout when taken out. The first point can be taken care of, as far as possible, by proper construction of the furnace; the second can best be taken care of by immersing the pieces to be tempered in the oil before starting to heat, and letting the pieces remain in the oil and be heated with it to the temperature required. In such a case, one should, of course, have more than one furnace, or else after each operation take the hot oil out and refill the tank with cold. The method described is very much better than the one frequently used of immersing the pieces in a bath which already has the required temperature and then letting them remain long enough to attain the heat of the bath throughout, as a furnace yet has to be designed which will maintain a uniform heat for even as short a time as is required for this operation. Furthermore, it is not necessary that a piece to be tempered be held in the bath a certain length of time at the required temperature; the temperature desired need only be maintained long enough to insure that the piece has been evenly heated throughout.

When tempering to high heats, or, rather, when tempering to higher heats than the flash point of any tempering oils (650 to 700 degrees F.*) some other tempering fluid than oil must be used. Lead is the one usually employed. As it is impossible when using lead to let the pieces to be tempered be heated up with the lead, they must be immersed at the predetermined temperature and kept there until heated evenly throughout to the same temperature as the lead. It is claimed by many that it is easier to maintain a uniform heat in a lead bath than in an oil bath, but it has been found that, owing to the lead not circulating as readily, the temperature may vary considerably in different parts of the bath, and hence it is not very reliable.

Salt is another medium frequently employed for tempering heats between 575 and 875 degrees F. Salt fuses at 575 degrees F., but when immersing the pieces to be tempered the salt will immediately solidify around the cold pieces. When these are heated to 575 degrees, the salt will melt and the pieces should be withdrawn. This is not reliable, however, as the pieces, especially if large, will not have had time to be heated through before the salt melts. If a higher temper is required, it is, of course, only necessary to let the pieces remain in the bath and get the readings of the heat from a pyrometer. In all these

* There are tempering oils on the market claimed to have a flash test of 750 degrees, but it is doubtful if they ever have been found to stand this test. Heavy black cylinder oil has been found to stand a flash test of 725 degrees.

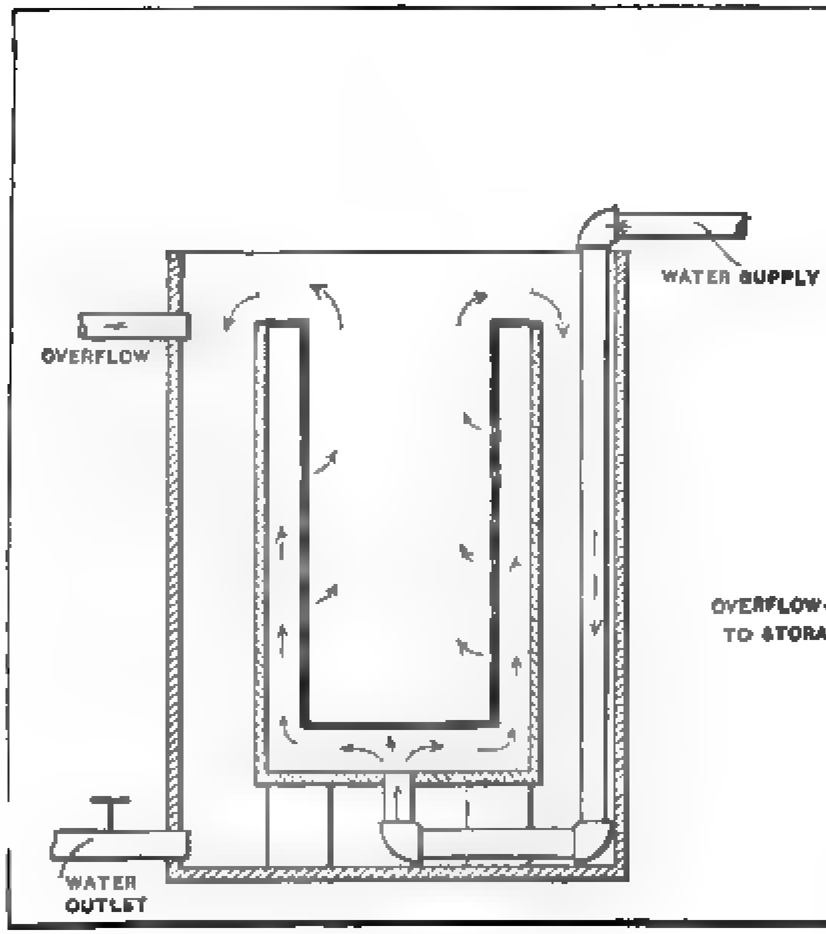

Fig. 9. Water or Brine Tank for Quenching Baths

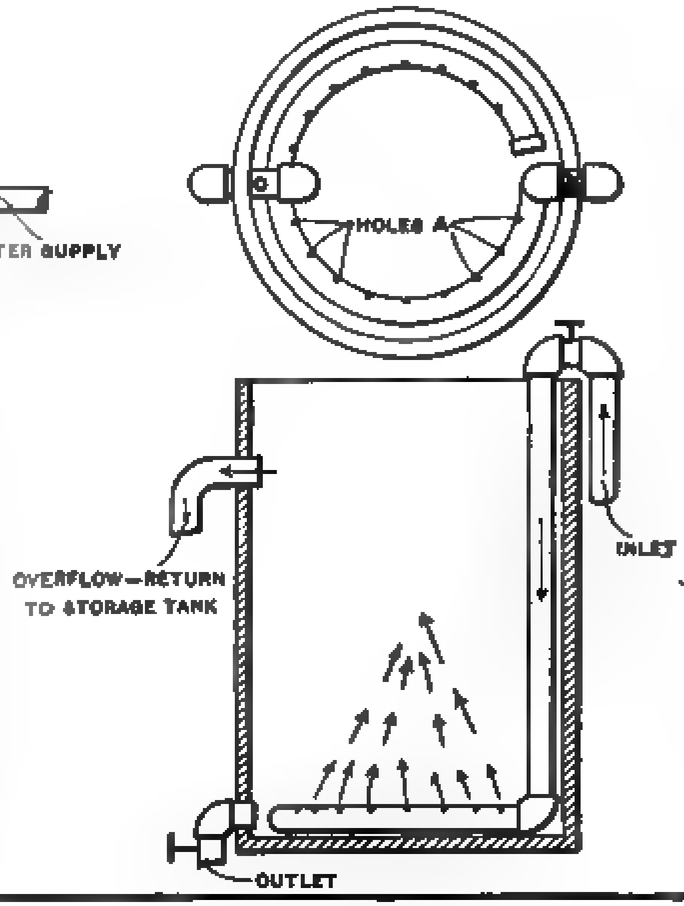

Fig. 10. Another Type of Water or Brine Tank

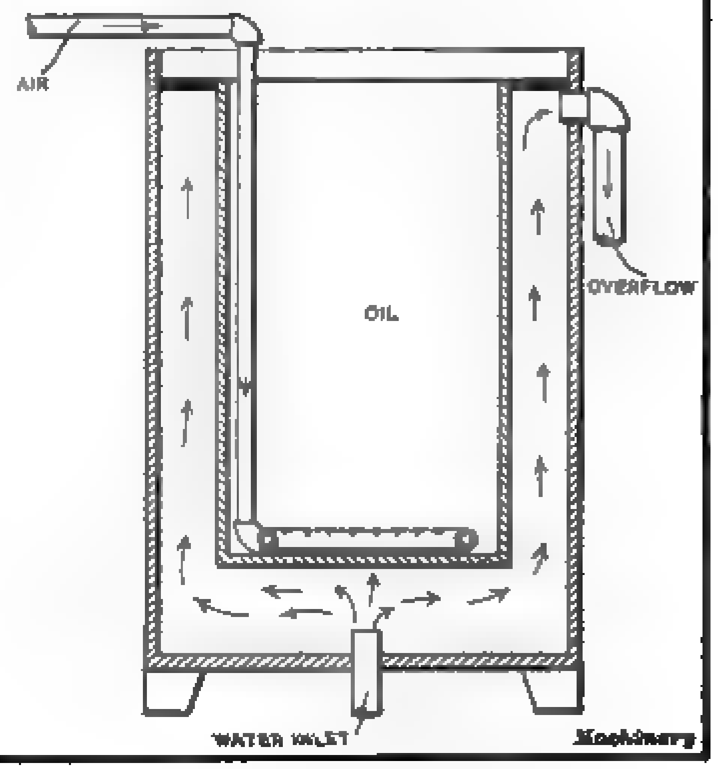

Fig. 11. Oil-quenching Tank with Water Circulated in an Outer Tank

methods, it is questionable if it is good practice to suddenly immerse cold pieces to be drawn into baths of such high temperatures. When a lower temper is required, and an oil tempering bath or furnace is not available, alloys of lead and tin can be used for as low heats as 400 degrees F. and of lead and antimony for 500 degrees F. However, this involves the inconvenience of keeping a large number of different alloys on hand, if it is desired to vary the temper heats. The following table for different alloys was compiled by Mr. O. M. Becker.

Melting Temperatures of Lead—Tin Alloys

Lead	Tin	Melting Temperature, Degrees F.	Lead	Tin	Melting Temperature, Degrees F.
14	8	420	24	8	480
15	8	430	28	8	490
16	8	440	38	8	510
17	8	450	60	8	530
18.5	8	460	96	8	550
20	8	470	200	8	[illegible]

The oils for tempering baths specified below are given for the sake of convenience only; the statements are based upon the findings of thorough experiments. There may, of course, be many other oils just as good that have not been tried.

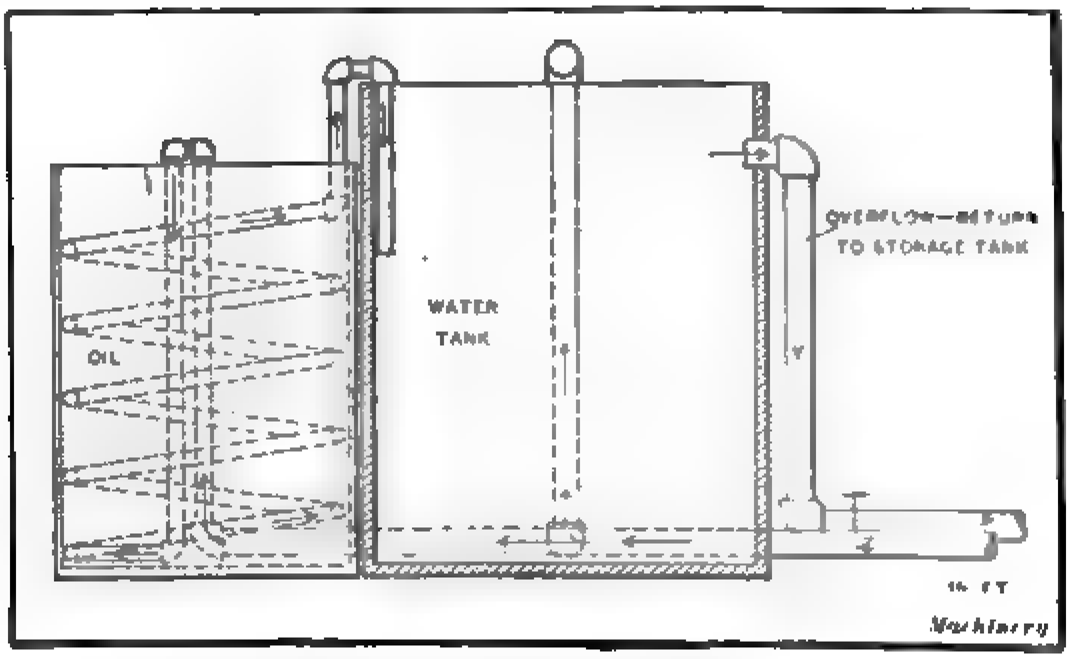

Fig. 13. Water and Oil Tank Combined

(1) Walter A. Wood, Boston, Mass., XXX tempering oil; as cheap in initial expense as any; good lasting qualities.

(2) Frankfort tempering oil, Strong, Carlisle & Hammond Co., Cleveland, Ohio.

(3) Fish oil, cottonseed or linseed oil may also be used. In many cases these are mixed with high fire and flash test mineralized oils.

Tests and Analysis

The analysis and test results of oils when new (not used) as compared with those of oils which have been used such a length of time as to render them practically valueless will be found interesting.

	Tempering Oil W. A. Wood New	Tempering Oil W. A. Wood Old (thick)	Lard and paraffin oil mixed (half and half) used for quenching New	Lard and paraffin oil mixed (half and half) used for quenching Old (thick)
Flash point	550	475	400	380
Fire test	625	550	475	450
Mineral oil, per cent	94	30	25	10
Saponifiable oil, per cent	6	70	75	90
Specific gravity	0.920	0.950	0.912	0.925

Houghton tempering oil: flash point, 696 degrees; fire test, 685 degrees; specific gravity, 0.900.

Frankfort tempering oil: fire test, 670 degrees.
Frankfort quenching oil: fire test, 500 degrees.
Paraffine oil (Underhay): fire test, 450; specific gravity, 0.912.
Lard oil (Bleecker): fire test, ——; specific gravity, 0.920.

The great difference in tests and analysis between new and used oils should be noted; oils used constantly at high heats will gradually lose the "mineral" part of the oil, the more so the higher the heat used. A tempering bath can therefore be prolonged in life by adding

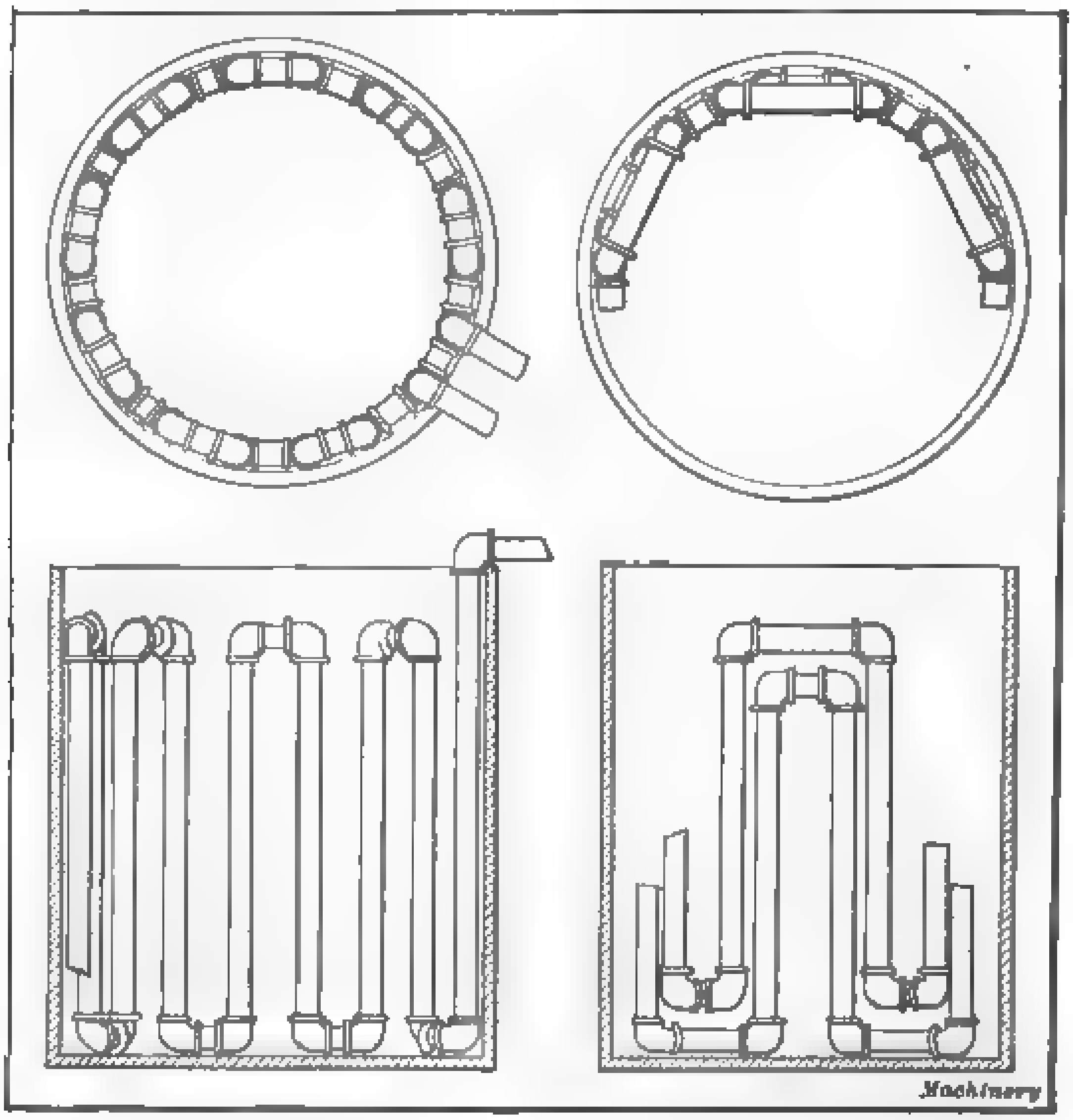

Fig. 13. Ordinary Type of Quenching Tank

Fig. 14. Oil-quenching Tank with Water and Steam Coils

to it now and then new mineral oil. To lengthen the life of the bath high heats should be avoided as much as possible.

Receptacles and Furnaces used in Quenching and Tempering

The main point to be considered in a quenching bath is, as mentioned, to keep it at a uniform temperature so that successive pieces quenched will be subjected to the same heat. The next consideration is to keep the bath agitated, so that it will not be of different temperatures in different places. If thoroughly agitated and kept in motion, as is the case with the bath shown in Fig. 9, it is not even necessary to keep the pieces in motion in the bath, as steam will not be likely to form around the pieces quenched. Experience has proved

that if a piece is held still in a thoroughly agitated bath, it will come out much straighter than if it has been moved around in an unagitated bath. This is an important consideration, especially when hardening long pieces. It is, besides, no easy matter to keep heavy and long pieces in motion unless it be done by mechanical means.

In Fig. 9 is shown a water or brine tank for quenching baths. Water is forced by a pump or other means through the supply pipe into the intermediate space between the outer and inner tank. From the intermediate space it is forced into the inner tank through holes as indicated. The water returns to the storage tank by overflowing from the inner tank into the outer one and then through the over-

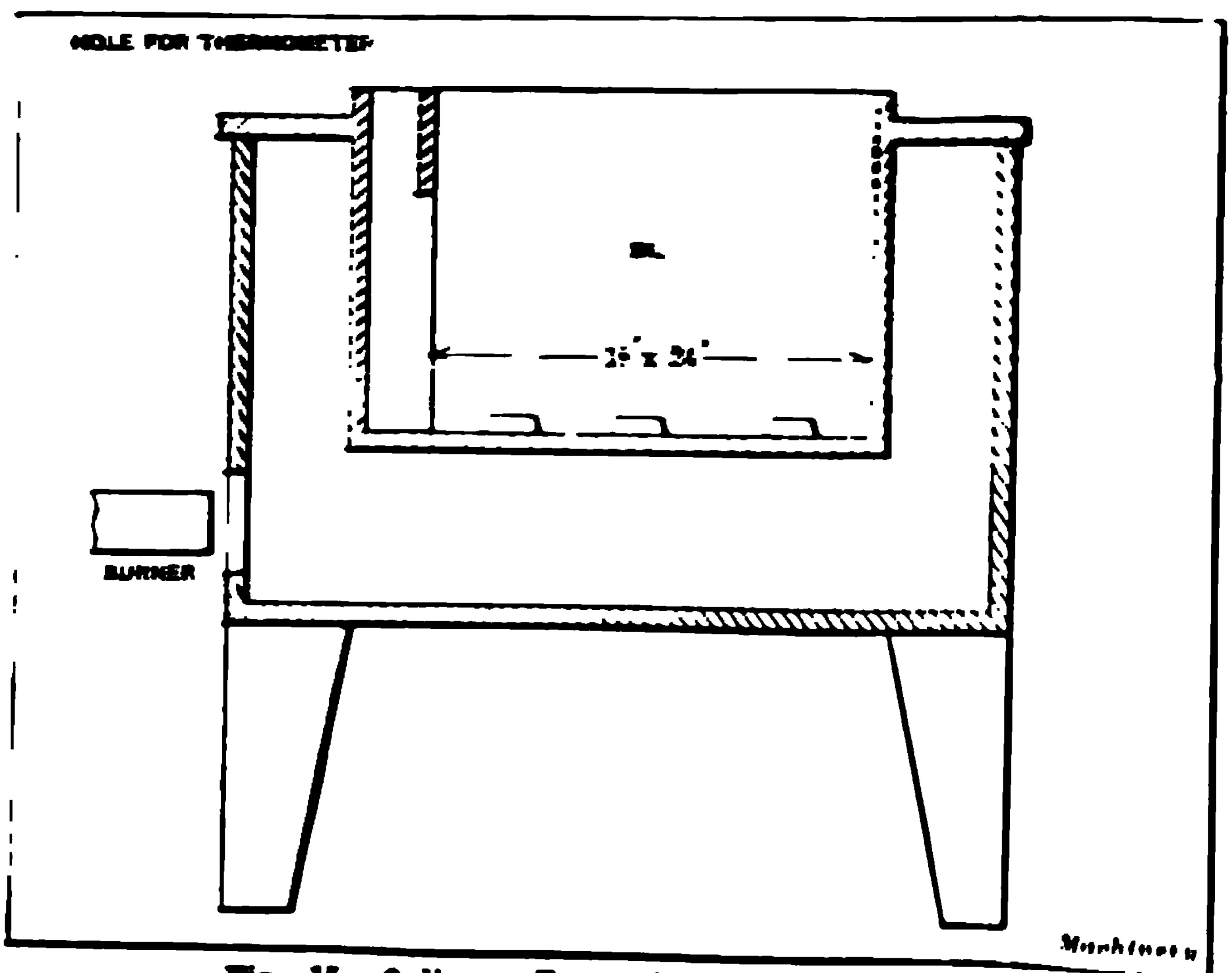

Fig. 15. Ordinary Type of Tempering Furnace

flow pipe as indicated. In Fig. 10 is shown another water or brine tank of a more common type. In this case the water or brine is pumped from the storage tank and continuously returned to it. If the storage tank contains a large volume of water, there is no need of a special means for cooling. Otherwise, arrangements must be made for cooling the water after it has passed through the tank. The bath is agitated by the force with which the water is pumped into it. The holes at *A* are drilled on an angle, so as to throw the water toward the center of the tank. In Fig. 11 is shown an oil quenching tank in which water is circulated in an outer surrounding tank for keeping the oil bath cool. Air is forced into the oil bath ... agitated.

Fig. 12 shows a water and oil tank combined. The ... by a coil passing through it in which water is circul... passes into the water tank. The water and oil bath ... agitated.

Fig. 13 shows the ordinary type of quenching tank cooled by water forced through a coil of pipe. This can be used for either oil, water or brine. Fig. 14 shows a similar type of quenching tank, but with two coils of pipe. Water flows through one of these and steam through the other. By this means it is possible to keep the bath at a constant temperature.

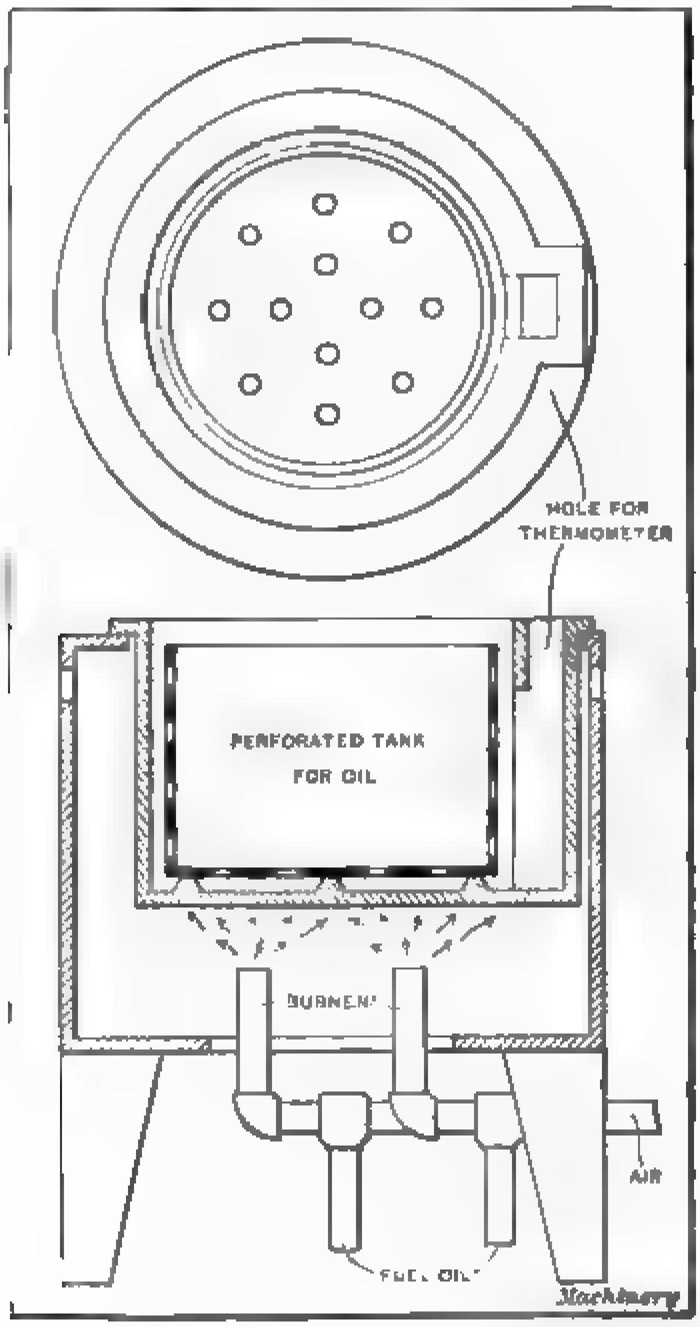

Fig. 16. Special Tempering Furnace with Perforated Oil Tank

In tempering furnaces the only really important consideration is to insure that the furnace is so built as to heat the bath uniformly throughout. It is doubtful if there can be found a tempering furnace on the market that will fill this requirement entirely, although many give good results in general. It is never safe, however, to let any tools being tempered rest against the bottom or sides of the tank, as no matter how scientifically the furnace may be built these parts are, in most cases, hotter than the fluid itself. It is, of course, just as important not to let the thermometer rest against any of these parts in order to insure correct readings. After the pieces tempered are taken out of the oil bath, they should immediately be dipped in a tank of caustic soda (not registering over 8 or 9), and after that in a tank of hot water. This will remove all oil which might adhere to the tools.

Fig. 15 shows an ordinary type of tempering furnace. In this the flame does not strike the walls of the tank directly. The tools to be tempered are laid in a basket which is immersed in the oil. In Fig. 16 is shown a tempering furnace in which means are provided for preventing the tools to be tempered from coming in contact with the walls or bottom of the furnace proper. The basket holding the tools is immersed in the inner perforated oil tank. This same arrangement can, of course, be applied to the furnace shown in Fig. 15.

...ilers.
...r Furnaces and Chimneys.
...d Water Appliances.
...m Engines.
...m Turbines.
...ps, Condensers, Steam and Water ...ing

...E DESIGN AND RAILWAY SHOP PRACTICE

...motive Design, Part I.
...motive Design, Part II.
...motive Design, Part III.
...motive Design, Part IV.
...motive Building. — Main and Side ...ds.
...motive Building. — Wheels, Axles; ...ving Boxes.
...motive Building. — Cylinders and ...ames.
...motive Building.—Valve Motion.
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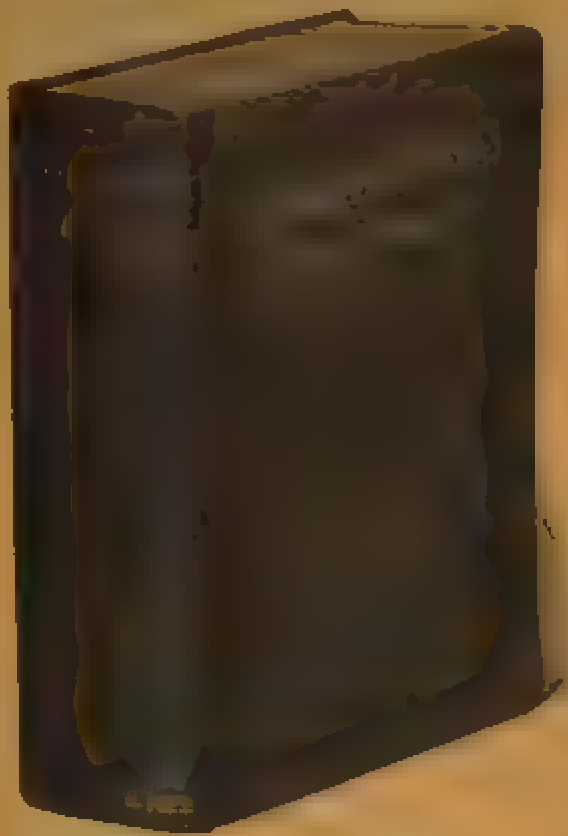

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ALLOY STEELS

THEIR COMPOSITION, CHARACTERISTICS, STRENGTH AND HEAT-TREATMENT

BY E. F. LAKE

MACHINERY'S REFERENCE BOOK NO. 118
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NUMBER 118

ALLOY STEELS

By E. F. LAKE

CONTENTS

CHAPTER I

NICKEL STEEL

Nickel steel is used to a large extent in the construction of high-grade machinery, and can be purchased in the open market in almost any percentages of nickel up to 35 per cent, and with the carbon component varying between 0.10 and 1.00 per cent. Nickel was added to carbon steel as the result of investigations which were started for the purpose of overcoming the "sudden rupture" that is inherent in all carbon steel. This property or tendency of carbon steel to rupture is the subject of numerous investigations by the railroads of the country at the present time, owing to the many accidents that have occurred in the past few years due to broken rails. Nickel added to steel largely overcomes this tendency, and nickel steel is used successfully for parts of machinery that have to withstand severe shocks and torsion, such as the crankshafts and connecting-rods of internal combustion engines, propeller shafts, automobile axles, and other parts of a similar nature which have to withstand similar strains and stresses.

If nickel is added to steel in any percentage not exceeding 8 per cent, the tensile strength and the elastic limit of the steel will increase with the percentage of nickel. If the percentage of nickel is above 8 per cent, but less than 15 per cent, its effect on the steel becomes, for some reason, entirely neutralized and brittleness is produced. If the nickel percentage, however, is above 15 per cent, then the strength and elasticity become practically equal to that of the nickel steels with percentages of nickel less than 8 per cent. If the nickel percentage is increased above 20 per cent, the strength and elastic limit gradually decrease, but the elongation increases.

The elongation shows a slight rise until about 3 per cent of nickel is added to the steel, and after that it shows a rapid decrease, until the zone of brittleness is reached, when it becomes nil. With from 20 to 25 per cent nickel, the elongation again rapidly rises, and from that point to 100 per cent it shows a slight increase. The best results, therefore, in steels that are used for machine parts are obtained with a nickel content of 3½ per cent, although for some purposes 5 per cent nickel steel is used at a sacrifice of the elongation.

Beneficial Effects of Nickel in Heat Treatment

The qualities of carbon steel are susceptible of change by heat-treatment the same as are those of alloy steels, but the higher the carbon content is the more likely is the steel to burn and thereby reduce its strength, and it is extremely difficult to caseharden steels which contain more carbon than does mild steel without destroying their good qualities and strengths. By the addition of nickel

tendency to burn is largely overcome, and the susceptibility to heat-treatment is remarkable. This is best illustrated by Table I in which a nickel steel was given different degrees of hardness. Its composition was as follows: Nickel, 3 per cent; carbon, 0.30 per cent; manganese, 0.40 per cent; phosphorus, 0.05 per cent; sulphur, 0.04 per cent.

A good quality, open-hearth, 0.30 per cent carbon steel, as received from the mill in the untreated state, shows the same strength as the untreated nickel steel in Table I, but it cannot be raised to much more than one-half of the strength of the nickel steel in its hardest state, and even then it is much more liable to fracture under shock tests.

Nickel increases the ability of steel to withstand shock stresses even though the shape be intricate and lightened with holes. When properly combined with carbon, it largely removes the tendency of crystallization, and the steel may be casehardened without fear of the core being brittle. If high in carbon, however, it will not stand local hardening, but may be hardened in oil without difficulty.

TABLE I. STRENGTH OF NICKEL STEEL AT DIFFERENT DEGREES OF HARDNESS

Hardness	Tensile Strength, Pounds per Square Inch	Elastic Limit, Pounds per Square Inch	Elongation in 2 Inches, Per Cent	Reduction of Area, Per Cent
Annealed	88,000	60,000	28	58
Medium hard	130,000	130.000	20	6
Hard	220,000	190,000	12	37
Very hard	225,000	225,500	8	19

Machinery

What the Microscope Reveals in Testing Steels

Steel subjected to different heat-treatments shows different properties when examined under a microscope, and microscopy is, therefore, becoming one of the methods of examining and testing different steels. If we take a piece of steel containing less than 0.85 per cent of carbon, polish it, attack it with a few drops of picric acid and examine it under a microscope, the results will differ according to its composition and the treatment it has undergone. In a piece of steel that has been cooled slowly, small dark masses will appear which are more numerous the closer the carbon is to 0.85 per cent.

Next, heat this steel to 1400 degrees F., or a dull red, and quench in water, then polish, attack with picric acid, examine under the microscope as before, and it will show extremely fine lines intersecting each other in the direction of the sides of an equilateral triangle. Therefore, it is evident that by annealing or heating and quenching this steel we can change its structure, and its condition *is readily* determined by the aid of a powerful microscope.

Other molecular changes take place in heat-treating steels and some of these are governed by the carbon contents. If certain steels are given the heat-treatments just described, the average blacksmith would try them with a file, and if the file bites as well as it did before heat treating, he would throw the steel out as not hardened, yet transformations have taken place, and tests would show that the tensile strength and elastic limit have been raised while the elongation and reduction of area are reduced In the case of the nickel steel of which Table I shows the test, these transformations have caused a variation in strength from 88,000 pounds to 225,000 pounds per square inch, this would have been considered impossible a few years ago.

TABLE II. EFFECT OF HEAT-TREATMENT ON NICKEL STEEL OF THE FOLLOWING COMPOSITION

Nickel, 2.51 per cent; Silicon, 0.26 per cent, Carbon, 0.32 per cent, Manganese, 0.48 per cent, Phosphorus, 0.023 per cent, Sulphur, 0.032 per cent

Treatment	Tensile Strength, Pounds per Sq. In.	Elastic Limit, Pounds per Sq. In	Elongation in 2 Inches, Per Cent
Quenched at 1600° F	225,000	208,000	4
Quenched at 1600° F., tempered at 600°	215,000	201,000	6
Quenched at 1600° F., tempered at 800°	190,000	150,000	9
Quenched at 1600° F., tempered at 1000° .	170,000	145,000	12
Quenched at 1600° F., tempered at 1200°..	155,000	125,000	14
Quenched at 1600° F., tempered at 1400°..	135,000	98,000	17
Quenched at 1600 F., tempered at 1600°..	104,000	65,000	24

Machinery

Thus annealing, hardening and tempering steel are resorted to for raising the tensile strength, elastic limit, and its ability to withstand shock and torsional stresses, as well as to put a fine cutting edge on tool steels.

Need for Annealing

In heat-treating steels for strength, and especially nickel steel, it should always be remembered that hardening by quenching produces internal strains which can only be removed or destroyed by tempering or drawing after quenching. Thus nickel steel cannot be used in its hardest state, in which it has the highest tensile strength and elastic limit; but the piece must be tempered, thereby reducing the strength and increasing the elongation in order to reduce the brittleness as well as the internal strains caused by hardening These internal strains may also be caused by forging, hammering or working, and the best results will be obtained if the steel is annealed after each important operation

Liability of Nickel Steel to Warp, Decarbonize and Cra

Three things work to the detriment of nickel stee'
always be taken into consideration when hardening it.

always warps in quenching; second, it may be decarbonized in heating; and third, fissures and cracks might occur in quenching. There are several rules which can be followed to minimize the tendency of steel to warp in quenching. If a piece is cut from stock that has been subjected to some mechanical treatment, it is very liable to be deformed on being heated, and it is undeniable that of the deformations attributed to the hardening process, a large part are due to the heating which precedes quenching, and results from the use of metal which has been mechanically worked. To overcome this, the steel should be thoroughly annealed before it is machined to size, so that the metal will be in a state of repose.

In quenching, the piece should be immersed in the bath in the direction of its principal axis of symmetry, so that the liquid can cover the greatest possible surface, and it should never be thrown into the bath. Thus a shaft should be immersed vertically and a gear wheel perpendicular to its plane. The piece should also be agitated in the bath so as to destroy the coating of vapor which usually forms around the piece and prevents its cooling rapidly.

To reduce the tendency to decarbonize, it is necessary to provide against oxidation; therefore, the pieces must be prevented from coming in contact with the gases. This can be done by placing the pieces in a protecting retort, or by using a metallic heating bath, such as lead.

Fissures or cracks which occur in hardening are caused by the different parts of the piece cooling unevenly, thus producing internal stresses of enormous proportions. These fissures may be prevented by reducing the rate of cooling in three different ways. One method is to cover water with oil from one inch to one inch and a quarter in depth. The second is to cool the pieces in a bath of a comparatively limited volume, so that the cooling is followed by a slight tempering, and the third is to withdraw the piece from the bath before it is completely cooled. This last requires considerable skill, if uniform results are to be obtained.

Nickel Steel for Gears

Nickel steel, when carbonized, is one of the best steels on the market for gears, as different tests have shown that 2 per cent of nickel added to the ordinary carbonizing steel will double, and in some cases more than double, the tensile strength after carbonizing, and these tests would prove that nickel steel should be used for carbonizing wherever the difference in price will warrant doing so. It is from 2 to 2½ cents per pound higher in price than the ordinary carbonizing steel, but the greater safety in manufacturing, and a consequent decrease in the number of spoiled pieces, will largely balance this difference in price.

The different materials used in carbonizing have different effects as to the penetration of the carbon and the time required for a certain

penetration; but a general rule for the rate of penetration at different degrees of temperature is as follows, the time being eight hours:

DEPTH OF PENETRATION OF CARBONIZING MATERIAL AT DIFFERENT TEMPERATURES

Temperature, Degrees F.	Depth of Penetration, Inch	Temperature, Degrees F.	Depth of Penetration, Inch
1300	0.000	1750	0.110
1475	0.0195	1800	0.125
1565	0.039	1850	0.165
1650	0.0625	1900	0.195
1700	0.080	....	....

Thus it will be seen that a rise in temperature of 150 degrees doubles the rate of penetration, and in one case a rise of 90 degrees has doubled it.

With the temperature held stationary at 1850 degrees the speed of penetration is as follows:

Time, Hours	Depth of Penetration, Inch	Time, Hours	Depth of Penetration, Inch
¼	0.000	4	0.500
½	0.020	6	0.800
1	0.310	8	1.200
2	0.400	..	....

The steel used for carbonizing should not contain over 0.20 per cent of carbon, and the manganese component should be low, as this has a tendency to produce crystallization in annealing, and cause brittleness.

The carbonizing material used should be of a definite composition which does not act abruptly, such as 60 per cent powdered charcoal and 40 per cent carbonate of barium. Two rules might be followed in treating: one is to carbonize at 1600 degrees F., cool to 1400 degrees, and quench; and the other is to carbonize at 1850 degrees, quench at 1650 degrees, reheat, and quench a second time at 1400 degrees F.

Nickel steel is not as high a grade of steel as nickel-chrome steel or the newer vanadium steel, but it stands a good second to these at about two-thirds the price, and is so much more easily machined and forged than nickel-chrome steel that it is often used in preference to the higher grades.

Care Required in Forging and Working

In forging, great care must be taken to keep this steel at a high full forging heat and never hammer or roll it below this temperature, as cracks are then liable to appear. A great deal is said among the users of nickel steel about its cracking badly and being defective, and if defects occur in the bloom, they will almost always show up somewhere in the finished product, but if the steel is properly rolled and forged these defects and cracks will not appear. Where carbon steel has been used for automobile axles and given way from fatigue, crystallization or other causes, h[illegible] l steel has been substituted, and has given perfect

Proportion of Carbon

Frequently it is stated in advertisements and elsewhere that a 2 per cent nickel steel is used for various parts of a machine, but this means nothing by itself, as the properties of the steel depend as much upon the carbon content as on the nickel. To illustrate, one nickel steel that is largely used, and is the best for certain purposes, contains 2 per cent nickel and 0.12 per cent carbon. It has a high

TABLE III. INFLUENCES OF DIFFERENT PERCENTAGES OF NICKEL IN NICKEL STEEL

Per Cent of Nickel	Tensile Strength, Pounds per Sq. In.	Elastic Limit, Pounds per Sq. In.	Elongation in 4.72 Ins., Per Cent	Treatment
1 to 1½	78,000	48,000	18	Water tempered at 1650° F.
2½ to 3½	97,000	82,500	15	Medium hard
2½ to 3½	80,000	68,000	20	Medium soft
2½ to 3½	85,000	60,000	23 to 19	Medium hard, structural
2½ to 3½	71,000	50,000	29 to 16	Medium soft, structural
4½ to 6	102,000	74,000	15	Hard, for strenuous work
4½ to 6	121,000	107,000	12	Hard, but annealed at 1600° F.
4½ to 6	88,000	68,000	20	Medium hard
16 to 18	199,000	114,000	6	Annealed at 1650°
22 to 26	110,000	45,000	40	Annealed at 1650°
22 to 26	114,000	50,000	35	Annealed at 1650°
30	80,000	28,000	44	Annealed at 1650°

Machinery

tensile strength and very little elongation, while another nickel steel, equally good for other purposes, contains 2 per cent nickel and 0.9 per cent carbon, and has a high tensile strength with a great elongation.

Table III shows the different percentages of nickel in steel made by one firm, and the strength due to different treatments. These steels have a carbon content ranging from 0.10 to 1.00 per cent. Those with the highest percentages of nickel are used mostly for valves, owing to their heat-resisting powers, combined with a great strength. Sometimes from 1 to 3 per cent of chromium is added to these valve metals to increase the elastic limit.

CHAPTER II

NICKEL-CHROMIUM STEEL

Of the many higher grades of steel which have been brought out in the past few years, nickel-chromium steel has, by both laboratory and practical tests, been placed in the front rank as the highest grade of steel manufactured, and it is used on all classes of high-grade machinery that require a steel of high tensile strength, high elastic limit, and a great resistance to shock and torsional stresses. It is one of the latest products of the steel maker. Ten or fifteen years ago this alloy of steel was comparatively little known, and it was a boast of the Germans "that the entire steel trust of the United States could not duplicate a Mercedes front axle." In the last few years that boast, however, has ceased to be true. To-day this alloy is being produced by a number of American steel makers at a price much below that which the Krupp works obtained for its highest grade of steel. Nickel-chromium steel is made in many different compositions, some of which are high in tensile strength, some in elastic limit, and others having different qualities, demanded by the different uses to which they are to be put.

The Effect of Chromium

Chromium added to steel in amounts up to 5 per cent increases the tensile strength and resistance to shocks, and diminishes the elongation, while further additions lower the tensile strength. The elastic limit, in pieces not annealed, is raised at first, and afterward lowered Chromium resembles carbon in its influence on the hardening qualities of steel It refines the grain remarkably, owing to its tendency to prevent the development of a crystalline structure Added to nickel steel, it overcomes the tendency of lamination and increases the elastic limit to figures that were impossible before it was brought into use. When nickel-chromium steel is given proper heat-treatment, it practically shows no grain or fiber, thus possessing a high power of resistance to shock This alloy also strongly resists the propagation of cracks which may be produced by sudden strains. Chromium intensifies the sensitiveness of the steel to the quenching process, and the resistance to fracture is higher than in carbon steel of the same degree of hardness; for this reason extreme hardness may be obtained. Two per cent or more of chromium added to steel makes it very difficult to cut cold, although a special tool steel is made which overcomes this difficulty to a large degree The influence of chromium on steel becomes decisive above a content of one per cent.

The effect of chromium on steel is best illustrated by the diagram, Fig 1, adapted from Austen's "Introduction to Metallurgy." The l- dotted line shows the tensile strength of annealed pieces, t

full line shows the elastic limit of annealed pieces, the upper dotted line shows the tensile strength of the steel when hardened, and the upper full line shows the elastic limit of the steel when hardened.

The reason why chromium steels do not fracture in heat-treatment as easily as carbon steels is due to the fact that in chromium steels the critical changes that take place when heating all steels to the hardening temperature take place more slowly. Chromium is also one of the best elements in a steel that is to be carbonized or casehardened, as it greatly increases the susceptibility of steel to heat-treatment and acts as a carrier of the carbon. Thus, in steels containing chromium, the carbon will penetrate to a much greater depth, and a higher percentage will be absorbed by the outer layer in a given time, than with any other kind of steel, especially carbon steel. The increase in

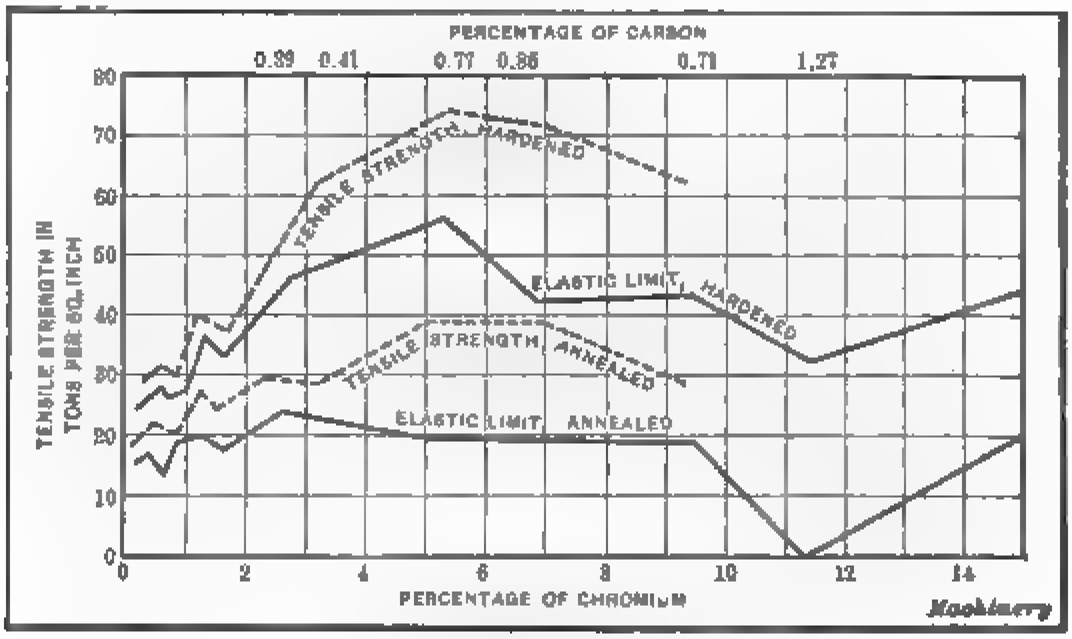

Fig. 1. Diagram Showing Effect of Chromium on Steel

depth of penetration of carbon is about 30 per cent of the penetration in ordinary carbon steels.

The chromium refines the grain of the steel remarkably, owing to its tendency to prevent the development of a crystalline structure. In the annealed state, every increase of chromium up to a content of 6.50 per cent raises the tensile strength, while the elastic limit is gradually raised until a chromium content of 3.00 per cent is reached. This latter remains constant until the chromium content has passed 9 per cent, but after this a rapid reduction takes place. In the hardened steels, both the tensile strength and the elastic limit increase until a chromium percentage of 5.00 per cent has been reached, and beyond this point both gradually decline.

When 2.00 per cent of chromium has been added to a steel that has a carbon content between 0.75 and 1.50 per cent, it combines great hardness with ability to resist shock. It is one of the best materials for piercing armor plate, and is also used in making projectiles. A chromium content of 3.50 per cent in a tool steel that contains 8.25 per cent of tungsten, gives the steel the well-known property of red

hardness, that is, the hardness is not drawn and the cutting edge is maintained when using the tool at a red heat. A high percentage of chromium is also added to a steel that is forged between layers of wrought iron or soft steel and hardened in water. This is used in safes, vaults, etc., to make them burglar proof, and is also used for plough-shares and similar work.

The presence of nickel in steel is very interesting in its influence, because, as mentioned in the previous chapter, when added in amounts up to 8 per cent, it increases the tensile strength, elastic limit, and elongation. Adding from 8 to 15 per cent of nickel produces a brittleness, and the mechanical properties are not ascertainable by experiment. With 20 per cent nickel a rapid rise in elongation is noticed, which increases very rapidly up to 25 per cent, after which the increase is more slow. Fig. 2 is a diagram from Roberts-Austen's "Metallurgy," which illustrates these points. Nickel sometimes produces in

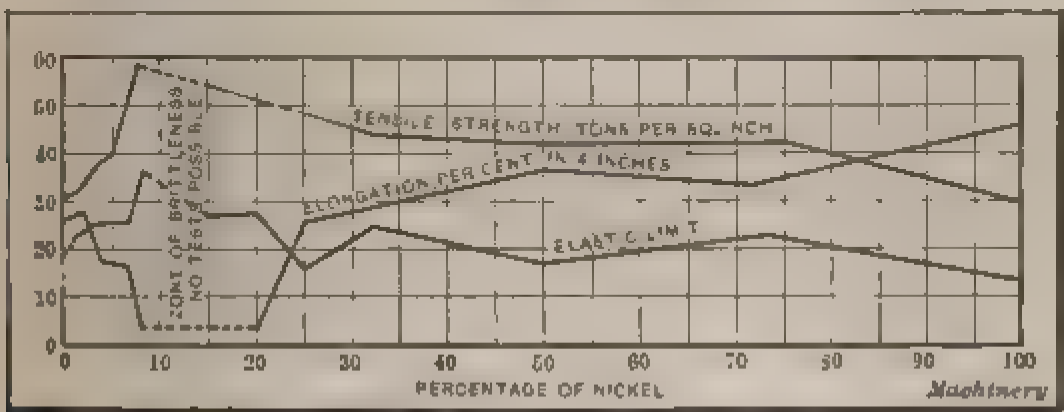

Fig. 2. Diagram Showing Effect of Nickel on Steel

steel a tendency to show laminations and to make it weak at right angles to the direction in which it is rolled. By the addition of chromium these laminations are removed, the metal is given a high degree of homogeneity, and the hardening can be performed more easily and without the danger of fissures appearing.

In nickel steel, the tenacity and elastic limit is much increased by positive quenching up to about 5 per cent nickel, especially with high percentages of carbon. Below 0.50 per cent carbon and 5 per cent nickel the reduction of area remains nearly unchanged, and the elongation but slightly decreases by heat-treatment, but when chromium is added these are both reduced nearly one half by heat-treatment.

Effect of Silicon

Silicon is sometimes used in nickel-chromium steel, as it prevents the formation of blow holes and neutralizes the injurious tendencies of manganese. The majority of these steels, however, do not contain silicon, as its exact influence is not quite clear, and it is difficult to obtain silicon in steel without the presence of maganese. This makes its direct action difficult to determine. In quenching, silicon seems to influence steel the same as carbon in many ways, but this largely depends on the co-existing amount of the latter as well as of man-

ganese. In general, only very small quantities are effective, and then only when the carbon content is low. Silicon will increase the tensile strength, but at the same time lower the elastic limit.

Effect of Manganese

Manganese is always a component of nickel-chromium steel, but over 0.40 per cent is seldom allowed, as a steel high in manganese is difficult to work cold, while otherwise nickel-chromium steel can be bent cold without difficulty. This has been proved by tests; in one case a connecting or piston-rod, after finishing, was bent double and showed no indications of cracks. Another rod was twisted two complete revolutions without injury. When the carbon is less than 0.50 per cent, and from 4 to 6 per cent of manganese is added, steel becomes so brittle that it can be powdered under a hand hammer, but by the addition of twice that amount of manganese the strength is restored. At 15 per cent maganese, again, a decrease in toughness, but not in transverse strength, takes place. With 20 per cent and more of manganese a rapid decrease takes place. The discovery of these properties brought out manganese steel which has some remarkable qualities.. The higher the percentage of carbon, the less manganese is necessary to bring about the result referred to.

Influence of Phosphorus and Sulphur

Phosphorus and sulphur are always components of steel, and probably more time and energy has been spent to get rid of these, or reduce them to a minimum, than on all other experiments. Phosphorus causes a "cold shortness" or brittleness in steel, and almost any quantity is injurious. No matter how high the tensile strength or elastic limit may be made by other components, if the phosphorus content is high, the metal will break when given shock tests. For this reason some object if phosphorus is present in amounts over 0.015 per cent, while others will allow as much as 0.04 per cent before they will agree that it is damaging to any serious extent. A high percentage of sulphur, on the other hand, causes a "hot shortness" or brittleness beyond a dull red heat, and is therefore not desirable when the metal is to be forged or worked hot. This component, however, is not as injurious as phosphorus.

Composition of Nickel-chromium Steels

The different combinations or percentages of the components of nickel-chromium steels are as varied as their makers, but the compositions obtained have resulted in a very high grade of steel. Thus nickel is used in percentages of from 1 to 5; chromium from 0.5 to 5; carbon from 0.25 to 0.45; silicon, when used, from 0.5 to 3; and manganese from 0.25 to 1. Table IV shows some of the nickel-chromium steels that are turned out by the different makers, both foreign and American, and their comparative strength. The first column shows one composition that is comparatively low in nickel and high in chromium, while the next three columns are low in chromium and

high in nickel, other components being about equal. The last two columns contain the specifications that were adopted by the Association of Licensed Automobile Manufacturers. The only difference between them is that one contains 0.45 per cent carbon and the other is 0.25 per cent. The physical characteristics of these two kinds are not derived from actual tests, but are the characteristics which they

TABLE IV. DIFFERENT COMPOSITIONS OF NICKEL-CHROMIUM STEELS AND THEIR STRENGTHS

No. of Sample	Composition in Per Cent: Nickel	Chromium	Carbon	Silicon	Manganese	Phosphorus	Sulphur
1	1.60	4.41	0.25	0.20	0.35	0.012	0.018
2	3.30	1.40	0.31	0.20	0.40	0.012	0.028
3	4.40	1.50	0.25	0.24	0.78	0.018	0.019
4	3.50	1.50	0.25	0.25	0.40	0.018	0.022
5	2.09	0.71	0.36	0.21	0.35	0.025	0.026
6	3.38	1.87	0.24	....	0.35	0.028	0.030
7	1.50	0.80	0.25	....	0.40	0.030	0.035
8	1.50	0.80	0.45	....	0.40	0.030	0.035

No. of Sample	Fully Annealed: Tensile Strength, Pounds per Square Inch	Elastic Limit, Pounds per Square Inch	Elongation in 2 Inches, Per Cent	Reduction of Area, Per Cent	After Heat-treatment: Tensile Strength, Pounds per Square Inch	Elastic Limit, Pounds per Square Inch	Elongation in 2 Inches, Per Cent	Reduction of Area, Per Cent
1	126,000	115.000	28	64	185,000	160,000	14	48
2	115,000	95,000	24	42	155,000	132,000	18	16
3	......	......	..	..	164,000	138,000	12	25
4	126,000	115,000	28	64	......	......		.
5	112,000	87,000	14	64	......	......		..
6	123,000	80,000	10	58	......	......		
7	85,000	65,000	20	50	180,000	100,000	12	30
8	90,000	65,000	18	35	180,000	140,000	8	20

must possess when a test is made from a ⅞-inch test bar, rolled from every heat and from two separate ingots. The actual tests may show much higher figures, as these are the lowest figures at which the steel will be accepted. The phosphorus and sulphur may, of course, be lower, as the percentage given is the highest that will be allowed. To the tests in this table there should be added a shock test, as all of the tests given might be satisfactory in their results, and yet, if too high in phosphorus, the metal would not stand shocks and torsional stresses.

The steels in the table which are high in carbon are used principally for gears, and are the highest grades of steel in the market, either foreign or domestic, for this purpose. The nickel-chromium steels shown

in the table that contain 0.25 per cent carbon are more extensively used than those with higher carbon content, as they are forged more easily, and are machined and worked with less difficulty. These steels are used where great strength is demanded, combined with a light weight; hence, in automobile construction they are used for such parts as crankshafts, sprocket shafts, rear driving shafts, propeller shafts, axles, wheel pivots, and piston rods. Some racing cars have been built with all the working parts, as well as the frame, of nickel-chromium steel. These nickel-chromium steels are not as readily drop-forged as the ordinary carbon steel, and, therefore, the difference between consecutive die forms should be less than in those used for ordinary steel. In forging, the metal should be heated to about 1380 degrees F., and kept at about that point until the operation is completed. Care must also be taken not to overheat or underwork the metal, as this produces a coarse grain, which will show a low percentage of reduction of area, and the metal will be condemned on account of its inability to withstand the shock stresses. The best forging process is undoubtedly the one using the hydraulic press, as with this the metal is slowly squeezed into the die, thus allowing the mass time to assume its new shape. The formation of crystals will not be able to take place, and the metal will be of a finer grain, with great density, producing less internal stresses and closing up any flaws which might have been in the center of the ingot. In hammer forging, unless the hammer is a large, slow-moving one, only the shell of the forged piece is affected, as the blows will not penetrate to the center.

Heat Treatment

Nickel-chromium steel is nearly always heat-treated, and great care should be used in doing this, as it is very easy to destroy the good qualities of the metal by inferior workmanship in this respect. The factors which influence the results of heat-treatment are:

First: The physical and chemical components of the metal.

Second: The gases and other substances which come in contact with the metal while heating.

Third: The form of the temperature rise curve for each unit of the metal.

Fourth: The highest temperature given to each unit of the metal.

Fifth: The length of time at which the metal is kept at the maximum temperature.

Sixth: The form of the temperature drop curve for each unit of metal.

At about 570 degrees F. most steels lose their ductility and are not capable of resisting the strains of unevenly heated metal. Therefore, the temperature rise curve up to this point should be a gradual one; after this it may be as rapid as possible without overheating. Care must be taken not to overheat or burn the metal, as it is almost impossible to bring it back to its former high standard.

Nickel-chromium steel should be annealed after it has been worked and before heat-treatment, in order that it may return to its natural state of repose, as machining, forging, hammering, etc., is liable to throw it out of its homogeneity. It is annealed in a different manner from the ordinary grades of steel, it being heated to a temperature of about 1470 degrees F., kept at this heat for four hours and then allowed to cool slowly in a slow-cooling furnace, or by packing in ashes or charcoal, the latter being preferred. If carbonizing is resorted to, this steel should be annealed, after carbonizing, as described above.

To harden this steel, it should be heated to about 1470 degrees F. and made as hard as possible by quenching in oil or water, after

TABLE V. CUTTING SPEEDS FOR DIFFERENT GRADES OF STEEL

Depth of cut $\frac{3}{16}$ inch and feed $\frac{1}{16}$ inch

Kind of Steel	Cutting Speed in Feet per Minute	Pounds of Turnings per Hour
Steel with 0.10 per cent of carbon	100	295
Steel with 0.20 per cent of carbon	75	222
Steel with 0 30 per cent of carbon	63	176
Steel with 0.40 per cent of carbon	51	150
Steel with 3.50 per cent of nickel	55	163
0.75 per cent nickel, 0 80 per cent chromium, and 0.25 per cent carbon	50	148
1.50 per cent nickel, 0.80 per cent chromium, and 0.25 per cent carbon	45½	135
Steel with 1 5 per cent nickel, 0 80 per cent chromium, and 0.45 per cent carbon	35	103

Machinery

which it can be drawn to the different degrees required. Gears should be drawn by heating to 480 degrees F. to remove the internal strains. This makes the hardest and toughest gear which it is possible to produce. It will stand an enormous amount of wear and shock stresses, and it is very difficult to break out a tooth with a sledge hammer.

The carbonizing should be done by carefully packing the pieces to be carbonized in a cast-iron pot, in a mixture of powdered bone and charcoal. This should then be heated slowly until the temperature is raised to 660 degrees F., after which the temperature can be raised as fast as desired until 2100 degrees F. has been reached. The steel should be kept at this temperature for at least four hours, after which it should be allowed to cool slowly by taking the pot out of the fire and permitting it to cool without removing the cover. This annealing, tempering, and carbonizing can only be done successfully and with positive assurance by the use of a furnace to which is attached a pyrometer, as the proper degrees of heat cannot be guessed at by the color of the metal.

Machining Nickel-chromium Steel

Nickel-chromium steel is more difficult to machine than ordinary steel, and can only be done successfully when it is fully annealed and with high-speed tool steel. Under these conditions it should be cut at the rate of 35 feet per minute, the cut being 3/16 inch deep, with 1/16-inch feed. The comparison between the machining of this and other steels is best illustrated by Table V.

This steel is only used where strength and lightness are more important than cost. In automobile construction, it is only used on the higher priced cars and for the parts which have to stand the largest amount of strains and stresses. Its ability to stand these stresses better than the ordinary carbon steel was demonstrated by one motor car builder, by taking two round bars 1⅛ inch in diameter, one of which was nickel-chromium steel and the other a mild carbon steel, fairly low in carbon, gripping both ends, leaving 9½ inches exposed and subjecting them to a bending operation, the bending being 9/32 inch out of the true position of the center-line of the bars. This bending was made, back and forth, with the carbon steel bar 20,000 times before it fractured, while with the nickel-chromium steel bar 250,000 bendings were made before this fractured. Other tests which have been made show similar results.

With the continued use of this grade of steel, its manufacture in larger quantities by the steel makers, and the improvements in machinery and cutting steels, it will no doubt be cheapened both in the production and in its manufacture into finished products, so that its use can become more diversified, and better wearing qualities, lighter weight and greater strength given to the working parts of many classes of machinery.

CHAPTER III

VANADIUM STEEL

Among the many new alloy steels which have been brought out in the last few years, the vanadium steels constitute one of the latest additions. These steels, in many different percentages of alloy, have been given numerous tests in order to determine the qualities of the steel and its action when submitted to the various strains and stresses it is liable to meet when put into actual use. These tests would seem to place it in the front rank of high-grade alloy steels, although it will be, after all, the actual use of this steel for the moving parts of machinery that will demonstrate to a certainty its wearing qualities, as well as its ability to withstand strains and stresses.

The mechanical engineers of the present day have been forced to become better metallurgists than they ever were in the past, in order to intelligently design high-grade machinery, as the so-called "mysterious" failures of steels are becoming more numerous and more pronounced every day. These failures of steel, which occur in high-grade alloys the same as in the Bessemer steel rails, although not as frequently, have proved to the engineers of to-day that the old custom of judging a steel by its resistance to static load and the amount it would stretch under that load is not always to be depended upon. The uses to which steel is put call upon it to resist strains applied in a totally different manner to that under which it was tested by simply pulling a bar until it broke.

In machine construction, those parts which are liable to failure while in use require high dynamic qualities, that is, resistance to repeated stresses, alternating stresses, simple repeated or alternating impacts, and fatigue, the latter being the outward and visible sign of the inter-molecular vibratory deterioration. Thus a new field is being opened out, and while vanadium affects steel in a manner that tends to increase the static strength, it also raises the dynamic properties to a very remarkable extent. Some recent tests of armor plate, made by the United States Government, give an illustration of this. In the past it has been the custom to make armor plate as hard as possible, and at the same time retain a high degree of strength. For this reason chromium was used as the principal alloy, and in many cases the only alloy, as it gave steel a hardness that was not obtainable in any other way. In the recent test spoken of, a vanadium-chrome steel was used with a hard outer shell and a very soft core, similar to the condition obtained by carbonizing. The result was that it withstood a much higher test of the impact blows delivered by the shots from a gun than the hard steels formerly used.

Vanadium and its Influence on Steel

In an article in MACHINERY, May, 1911, Mr. William B. Snow gives a brief review of the main characteristics of vanadium and vanadium steel. Although vanadium has been used to a considerable extent for a number of years as an alloy for steel, one frequently hears the question asked: "What is vanadium, and how do vanadium steels differ from other steels?" Vanadium is an element, the existence of which was first recognized by a Mexican, Del Rio, about the year 1800. A number of years later it was discovered that the remarkable qualities of Swedish iron were due to the presence of a small amount of vanadium in the native ore. It is only quite recently, however, that vanadium has been found in sufficient quantities for commercial use.

Pure vanadium is silvery white in appearance, and of very high melting point. In the pure state it has little or no practical application; for use as an alloy it comes in the form of ferro-vanadium, which usually contains from 30 to 40 per cent of vanadium. Vanadium is such a powerful alloy that it only needs to be used in exceedingly homeopathic doses to produce marked results. The use of as small an amount as 0.05 per cent of vanadium produces a strong scavenging action that indirectly toughens the steel to a most noticeable extent, by removing the oxide, nitrides, etc. The use of a larger amount—0.18 per cent, or more—causes a portion of the vanadium to combine with the ferrite or free carbonless iron in the steel, thereby directly toughening it.

Vanadium is very volatile in its action, and considerable difficulty is experienced in getting it to mix thoroughly and evenly with the steel. When put into crucible steels it has a particularly aggravating tendency to go to the bottom of the pot in a lump, where it is frequently found after pouring. The higher the percentage of the vanadium, the greater the difficulty experienced in getting it to mix properly with the steel. It is practically impossible to put over 1.25 per cent of vanadium into steel and keep it there, while most vanadium steels do not contain more than 0.25 to 0.30 per cent of vanadium.

In order to more fully understand its specific action, consider briefly what takes place when vanadium is put into steel. Steel consists of iron, with more or less carbon, sulphur, phosphorus, manganese, silicon, and, frequently, chromium and nickel. The carbon contained is combined chemically with a molecular portion of the iron. A molecule of this chemical compound alloys itself with twenty-one atoms of carbonless iron and the resultant alloy is distributed in spots, or patches, through the carbonless iron. This alloy is known technically as pearlite, and the free carbonless iron as ferrite. Part of the manganese unites chemically with the sulphur in the steel, forming striæ, or globules throughout the mass. The phosphorus and the silicon, also the larger part of the nickel—if used—are dissolved in the ferrite in what is known as "solid solution." The chromium is found as a constituent of the pearlite. When vanadium in a sufficient amount is used, it goes into solid solution, partly in the

ferrite, which it toughens, and partly in the carbide portion of the pearlite, which it strengthens.

Vanadium is also beneficial to steel in still another way, its use securing better results from the process of annealing, as will be seen from the following: When heat is applied to a bar of steel, as in annealing, it becomes sensibly hotter with each degree of heat applied, up to a certain point, known as the point of decalescence. When the steel reaches this point, further application of heat does not increase the sensible temperature, but instead, a change takes place in the steel itself; the pearlite becomes broken up, its carbides going

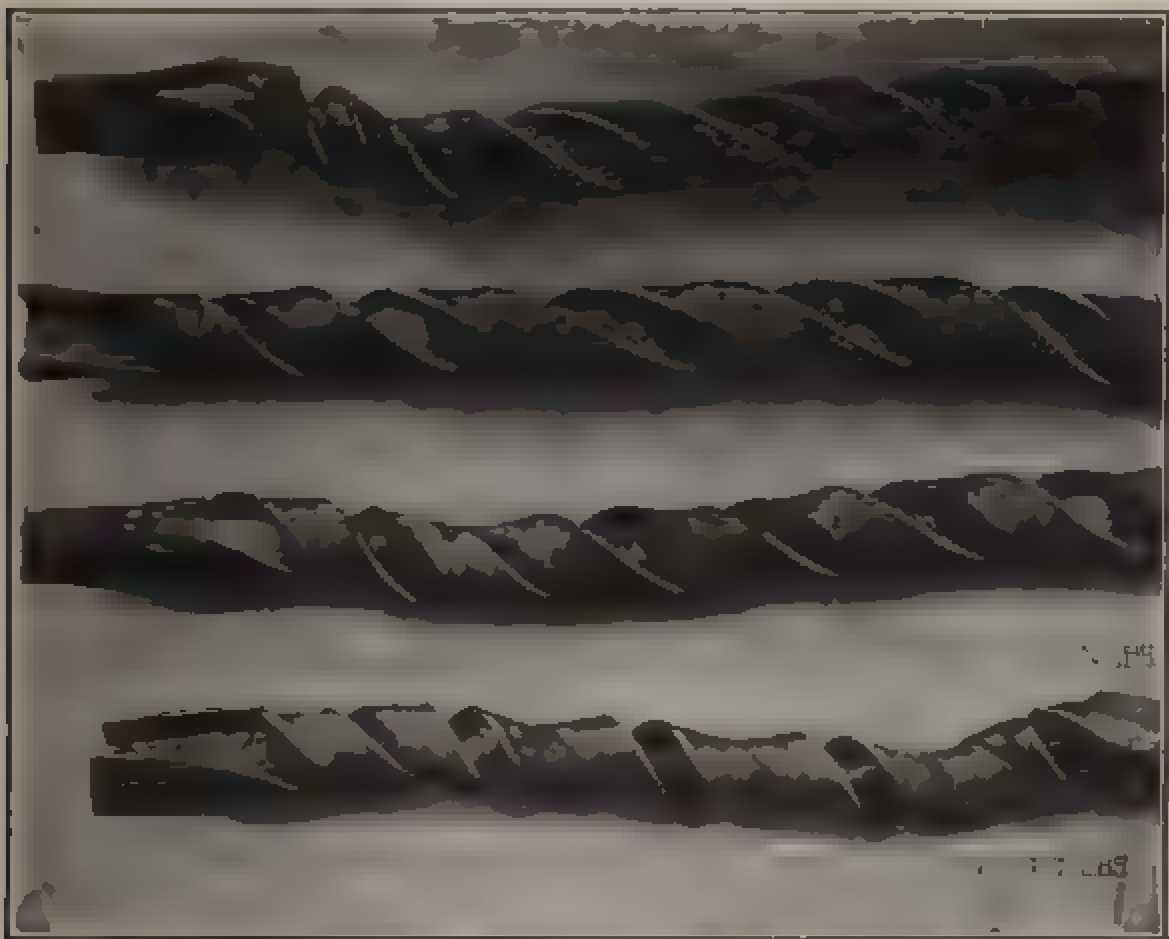

Fig. 8. Axle Steel Samples showing Difference in Physical Qualities. Length, 52 inches, Depth, 2 inches, Width, $1\frac{1}{2}$ inch. Thickness of Flanges, 3/16 inch at Edge, 3/8 inch at Web, Thickness of Web, 3/16 inch

into solid solution in the ferrite. When this change is completed, the sensible temperature of the steel again rises. In cooling, the reverse takes place, to a certain point, known as the point of recalescence, the steel cools regularly, then it apparently ceases to cool, and a change takes place in the steel itself. The dissolved carbides are thrown out of solution, and alloy themselves with the ferrite to re-form pearlite. When this change is completed, sensible cooling again proceeds.

Since the object of annealing is to break up the carbide areas and distribute them in small colonies, the steel is heated above the decalescence point, the temperature being maintained long enough to thoroughly decompose the pearlite—as well as to remove any mechanical strains that may have been locked up in the mass by previ-

ous manipulation under hammer and rolls. It is then cooled slowly through the recalescence point, care being taken to prevent chilling.

As a vanadium ferrite does not permit of the ready passage through it of the carbides re-precipitated at the recalescence point, the distribution of the carbides in a vanadium steel is remarkably even. This greatly increases the toughness and tenacity of the steel, in addition to the greater toughness already obtained with the background of vanadium ferrite (the portion of the vanadium that has gone into solid solution with the free carbonless iron).

Properties of Vanadium Steel

The peculiar properties of vanadium steel are best shown by the following comparative table of the physical properties of vanadium and other crucible steels:

Condition of Steel—Natural, as rolled	Tensile Strength, Pounds per Square Inch	Elastic Limit, Pounds per Square Inch
Carbon Steel	82,300	56,000
Chrome-nickel Steel	102,100	69,230
Chrome-nickel-vanadium Steel	118,100	87,500
Chrome-vanadium Steel	153,220	98,560
Condition of Steel—Annealed		
Carbon Steel	61,100	43,200
Chrome-nickel Steel	81,200	56,700
Chrome-nickel-vanadium Steel	96,350	69,300
Chrome-vanadium Steel	112,000	76,160
Condition of Steel—Oil tempered at 1500 deg., F., drawn to 600 deg. F.		
Carbon Steel	126,300	101,100
Chrome-nickel Steel	150,300	134,500
Chrome-nickel-vanadium Steel	163,700	152,300
Chrome-vanadium Steel	233,090	210,500

From the above table it is seen that the two most marked characteristics of vanadium steel are its high tensile strength (breaking point), and its high elastic limit (stretching point). Another equally important characteristic is its great resistance to shocks; vanadium steel is essentially a non-fatigue metal, and therefore does not become crystallized and break under repeated shocks like other steels. Tests of the various spring steels show that when subjected to successive shocks for a considerable length of time, a crucible carbon steel spring was broken by 125,000 alternations of the testing machine, while a chrome-vanadium steel spring withstood 5,000,000 alternations, remaining unbroken.

Another characteristic of vanadium steel is its great ductility. Highly tempered vanadium steel springs may be bent sharply, in the cold state, to an angle of 90 degrees or more, and even straightened again, cold, without sign of fracture; vanadium steel shafts and axles may be twisted right around several complete turns, in the cold state, without fracture. This property, combined with its great tensile strength,

makes vanadium steel highly desirable for this class of work, as well as for gears which are subjected to heavy strains or shocks upon the teeth.

In the matter of heat-treatment, vanadium steels will stand a wider variation of temperature without detrimental effect than other steels. One particular characteristic of vanadium steel is the evenness with which is hardens. Vanadium steels forge readily, and, in the annealed state, are no harder to machine than an ordinary steel containing the same percentage of carbon. In this respect they differ greatly from other steels of high tensile strength, in which the presence of a considerable amount of nickel renders machining extremely difficult.

The usefulness of vanadium as an alloy is not confined to steel alone; it is equally beneficial to other metals. Cast iron, brass and copper are much improved by the addition of a small percentage of vanadium, their strength and endurance being greatly increased. Castings from these metals show a finer grain and greater freedom from porousness through the use of vanadium. Aluminum, a particularly difficult metal to machine, is greatly benefited in this respect by the addition of vanadium, which not only renders it easier to work, but also insures its ready flow in the mold, producing sharp, even castings from difficult shapes.

The Practical Advantages of Vanadium in Steel

Vanadium, as mentioned, acts as a purifier on the metal, and very small percentages give the desired results; but if used in too large a percentage, it will spoil the metal. Sometimes the vanadium will perform this purifying action and leave but a trace to show on analyzing the steel, but in the majority of instances it stays in the metal. Vanadium steel, however, is the most difficult of all the alloy steels for the chemist to correctly analyze.

Vanadium has the property of elusiveness to a very marked degree, and must be handled by the steel maker very carefully in order to get the necessary results. It is, therefore, marketed in the form of ferro vanadium in the proportions of about two parts of iron to one part vanadium. For machinery purposes it is generally alloyed with steel in percentages of from 0.10 to 0.30 per cent, but it has been tried as a tool steel with as high as 3 per cent, and when this was compared with a 3 per cent tungsten tool steel by cutting a chilled white iron plate, and then collecting and weighing the cuttings, the vanadium tool steel was found to excel the tungsten tool steel by [illegible] per cent. It is used in manufacturing a tool steel by one steel maker, in this country, who uses vanadium in a small percentage, tungsten in a large percentage, chromium in a small percentage, and a few other ingredients in small percentages, and the results obtained from this steel show that it excels other tool steels by from 10 to [illegible] per cent in their cutting qualities.

Vanadium is not like nickel, chromium, [illegible] and other mineral elements used in high grade steel making, as it contains

within itself no virtues, except in its action as a purifier on the other elements. Its most successful application lies in the direction of steels such as chrome-vanadium or nickel-vanadium. In a technical sense it retards the segregation of the carbides, thereby producing in steel a high degree of homogeneity and a grain of great uniformity and fine texture. In retarding the segregation of the carbides, vanadium renders steel susceptible to great improvements by heat-treatment or tempering, and in this manner the steel can be prepared to resist wear and erosion. It also renders possible the natural formation of the "sorbitic" structure which is necessary in metals which have to withstand wear and erosion. Vanadium steel also has self-lubricating properties to a greater extent than other high-grade steels, hence it is more valuable for shafts running in bearings and for gears. It also produces soundness mechanically as well as chemically

TABLE VI.

Specimen	Tensile Strength in pounds per square inch	Elastic Limit in pounds per square inch	Elongation in 2 inches, per cent	Reduction of Area, per cent
A	82,500	50,000	30	66
B	116,000	90,000	21	71
C	165,000	147,000	11	61
D	165,000	147,000	16	59
E	200,000	185,000	11	56
F	228,375	......	..	..
G	198,750	190,000	9	34

and toughens the steel, thus conferring great powers of resistance to torsional rupture.

Chromium gives to steel a brittle hardness which makes it very difficult to forge, machine or work, but vanadium, when added to chrome-steel, reduces this brittle hardness to such an extent that it can be machined as readily as a 0.40 per cent carbon steel, and it forges so much more easily that the Ford front axle—shown twisted in Fig. 3—which is 52 inches long, 2 inches deep, of I-beam section, with the web only 3/16 inch thick, is being forged in three heats. The first heat is used to forge the straight I-beam part; the second heat is used to forge the arm for the steering-rod connection and the projections for the steering pivot on one end, while the third heat is required to forge the same on the other end of the axle. Automobile axles of similar design, when formed out of chrome-nickel steel, require from 15 to 20 heats to give them the proper shape, and even then the dies give a great deal of trouble. For this reason the nickel or chrome-nickel axles are usually forged in two halves, and welded together in the center by the electric welding process.

That vanadium steel can be machined as easily as ordinary carbon steel, that is, running at the same speed and using high-speed tools, is testified by the Ford Motor Co.: "We find in actual practice that vanadium steel costs no more than ordinary carbon steel and vastly less than nickel, because of the saving in machining, forging and

tempering, and the greater accuracy we are able to obtain, owing to uniformity of metal and the lighter weight of metal we are capable of using, owing to its great strength."

Fig. 3 shows the comparative amounts of torsion which vanadium and some other steels will stand by twisting. Table VI. gives results of tests on various kinds of steel. *A* is a 0.06 per cent carbon steel, heat-treated. *B* is a 0.07 per cent nickel steel, heat-treated. The others are all taken from the same bar of vanadium steel and sub-

TABLE VII.

Specimen	Tensile Strength in pounds per square inch	Elastic Limit in pounds per square inch	Elongation in 2 inches, per cent	Reduction of Area, per cent
1	88,000	64,500	29	59
2	98,750	67,500	25	77
3	127,500	110,000	14	59
4	147,000	140,750	17	57
5	165,000	155,000	16	55
6	176,500	175,000	7	27

jected to different degrees of heat-treatment. *F* merely shows the ultimate strength obtainable.

Vanadium steel can also be given a wide range of strengths together with hardness or softness by properly heat-treating. This is best shown by the accompanying Table VII. of test bars which were pulled on an Olsen testing machine by the Ford Motor Co. The test bars were all made out of one bar of steel. Specimens 1 and 2 are in their softest condition; specimen 3 is in the condition of an axle; specimens 4 and 5 are in the crankshaft condition; and speci-

TABLE VIII.

Kind of Steel	Pendulum Impact, Foot-pounds	Alternating Impact, Number of Stresses	Falling Weight on Notched Bar, Number of Blows	Rotary Vibrations, Number of Revolutions
Carbon axle stock.............	12.3	960	25	6,200
Nickel axle stock..............	14.0	800	35	10,000
Vanadium axle stock...........	16.5	2700	69	67,500
Vanadium crankshaft stock.....	12.0	1850	76	.....
Vanadium mesh gear stock....	6.0	800	..	.....

men 6 is in a mesh gear condition. Other tests have shown much higher strengths, but the remarkable features of these tests are the way the elastic limit has been brought up nearly to the tensile strength, and the high reduction of area.

While the static strengths before stated are and can be made the equal of almost any alloy steel, it is in the dynamic properties that vanadium steel excels all others, and these are becoming more and more the real tests of steel for use in moving machinery or where strains other than a direct pull are put upon it. These properties of vanadium steel as compared with carbon and nickel steel are shown by the tests given in the accompanying Table VIII.

CHAPTER IV

MANGANESE STEEL

The following information on the subject of manganese steel is, mainly, abstracted from a paper by Mr. F. E. Johnson, read before the Association of Engineering Societies, October 21, 1910.

Manganese steel was first successfully produced by the Hadfields in England about thirty years ago, and was known as "Hadfield steel." It was first made in the United States by the Taylor Iron & Steel Co., of High Bridge, N. J. About 1905 other foundries in this country took up its production, but they soon discovered that it was a very difficult metal to produce successfully, and comparatively few foundries are today engaged in manganese-steel making. In fact, the manufacture in the United States is almost entirely confined to two companies, the one mentioned above, and the Edgar Allen American Manganese Steel Co. The latter firm has two foundries, one at Chicago Heights, Ill., and one at Newcastle, Del.

We might define manganese steel as a metal of the following composition:

	Per Cent
Manganese	11.00 to 15.00
Carbon	1.00 to 1.20
Silicon	0.25 to 0.40
Phosphorus	0.06 to 0.11
Sulphur	0.02 to 0.06
Balance, iron.	

Variations from the composition given above have been tried, and steel has been made containing anywhere from 8 to 35 per cent of manganese, but commercial manganese steel contains at present about 10 to 15 per cent of manganese and 1 per cent of carbon, these two constituents being the chief factors in manganese-steel making. Great care must be exercised in the manufacture so that the percentages of these two constituents are in the right proportion. Too much carbon and not enough manganese makes the steel brittle.

Manganese steel is considered a very hard metal, because of the fact that it cannot be machined as readily as ordinary iron or steel. In fact, it is practically impossible to machine it with even the highest quality of tool steel. Tests made on the scleroscope indicate a hardness of about 30 for Bessemer steel, from 40 to 50 for manganese steel, and from 65 to 70 for chilled cast iron; yet it has been demonstrated again and again that manganese steel will outwear chilled cast iron many times over. In general, it is safe to say that it will wear from four to eight times as long, depending upon the purpose it is used for and the conditions under which it works. The secret of the resist-

ance of manganese steel to abrasive action seems to be due to its ability to "flow" or endure repeated distortion Under abrasive action it simply moves away from one place to another, but does not actually wear off. One can take, for example, a square corner of a piece of manganese steel and peen it over, and then pound it back to a square corner, and keep up this operation without actually being able to remove any material.

Manganese steel is very sensitive to heat. A statement given out by the Edgar Allen American Manganese Steel Co. contains some interesting information on this point Manganese-steel castings should never be heated, because if heated to a temperature of only 400 degrees F., they will lose their toughness and strength to a remarkable degree This applies to castings of plain design; castings of irregular design do not even stand as high a heat as 400 degrees F. A casting which is in perfect condition and free from internal stresses at the time it leaves the foundry is very likely to break or crack if heated The company strongly disclaims any responsibility for the breakage of any manganese-steel castings which have been heated after their shipment from the company's foundry.

Manganese steel will not become a permanent magnet; hence it is used for disks in magnetic hoists, as the smallest particle of iron or steel will not cling to it after the current is shut off. The tensile strength of early specimens, determined by Hadfield in England, was 150,000 pounds per square inch, with an elongation as high as 50 per cent. The average commercial steel of today, however, has a tensile strength of 82,000 pounds per square inch, an elastic limit of 45,000 pounds and an elongation of 30 per cent Forged manganese steel will give better results, but there is very little commercial forged manganese steel made at this time.

Manufacture of Manganese Steel

The manufacture of manganese steel is carried on with a great degree of secrecy, and for this reason full information on some of the processes employed cannot be given The steel is composed chiefly of a mixture of scrap iron and pig, this mixture being very carefully made up according to the predetermined composition of the steel The mixture is melted in an ordinary cupola such as is used in any foundry, and is then run into a converter and blown quite similarly to Bessemer steel This process, however, is carried out with great care and is directed by one man only, who operates everything from the central station or platform close to the converters. After the steel is blown, it is poured into large ladles from which the slag is removed The manganese, which has previously been melted in graphite crucibles under intense heat, is then added From the large ladles it is poured into sand molds which are practically the same as ordinary molds for cast iron

One difficulty with manganese-steel castings is the excessive shrinkage when cooling Manganese steel shrinks 5/16 inch per foot, which

is nearly three times as much as the shrinkage of ordinary cast iron. All ladles and molds are kept very hot so as not to chill the metal before it is poured, as in this case a homogeneous casting could not be produced. After the casting process is completed, the castings are all subjected to a heat-treatment, or both heat-treatment and water submergence. This part of the process is kept secret by the manufacturers.

Manganese-steel castings can only be successfully made to certain sizes as regards length and particularly as regards cross-sectional area, the thickness being the prime factor. The greatest thickness of any section that has been successfully cast, up to date, is about 4½ inches. It is also very difficult to cast small or thin sections, the lower limit being about ⅜ inch for ordinary castings. The reason that the thickness is so important is because of the after treatment, which apparently will only penetrate to a certain depth. Thin sections are limited by the flow of the metal.

Owing to the fact that manganese steel cannot be cut by ordinary cutting tools, all machining on manganese-steel castings must be done by means of grinding. Sometimes steel bushings and other pieces of ordinary soft steel are inserted in the molds and cast into the casting, making it possible to bore out, drill or tap the casting at certain places. For example, the hubs for car wheels may be provided with soft steel bushings, and soft steel inserts may be provided for set-screws, etc.

Uses for Manganese Steel

The uses of manganese steel are not very extensive at present, due partly to its high first cost, and partly to the difficulty of machining the steel. It is used mostly for castings subjected to heavy strains and shocks and excessive wear, such as the wearing parts of steam shovels, ore and rock crushers, mining machinery, etc. It is also used to a considerable extent for safes. When rolled and forged, it is used for rails, frogs and crossings. The use of manganese steel has made it possible to cut down the maintenance cost for many machines very materially.

It may be of interest to emphasize the fact that manganese steel has proved itself efficient when used in cases where it is subjected to shocks. An idea prevails among railway engineers that this steel will not stand shocks. As an experiment, therefore, a manganese-steel frog weighing 800 pounds was bent under a drop weight. The frog was subjected to 165 blows from a weight ranging from 1250 to 2500 pounds and falling from a height varying from 3 to 23 feet, the total energy exerted being nearly 1,700,000 foot-pounds. No fracture or impairment of any nature could be discovered. There are hundreds of manganese-steel frogs and cross-overs now in use. At the Northwestern Terminal, in Chicago alone, there are 200 frogs of this kind installed.

CHAPTER V

TITANIUM STEEL

Titanium is one of the elements that have been successfully used to improve the quality of steels. It has also been very successfully used for cast iron and for some of the non-ferrous metals The first heat of titanium steel made in America was poured in 1907, and since that time a great deal of investigation has been conducted and many experiments have been made. These tests have shown that when ferrotitanium has been added to steel or iron in very small quantities, it has greatly strengthened these metals and improved their qualities in other ways; it can now be considered one of the best of purifying elements that have been used in the manufacture of steel.

Titanium belongs to the same chemical group as silicon, and three other elements that are quite rare. It forms a compound with oxygen, called titanium dioxide (TiO_2), occurring in nature in three distinct forms, the principal one being the titaniferous iron ore so often encountered. In some respects it resembles carbon. Like many of the other elements, it is very difficult to control and make use of when a natural ingredient of the iron ores; it is therefore necessary to separate it in the electric furnace and manufacture it into ferrotitanium containing from 12 to 15 per cent titanium, about 6 per cent of carbon and 5 per cent of all other impurities, with the balance iron. This, when correctly added to steel or iron, can be made very beneficial. With this percentage of titanium, it enters into almost instant solution; but as titanium has a much higher melting point than iron, a higher percentage would cause the titanium to segregate and no beneficial results would be obtained.

While nickel, chromium, molybdenum and tungsten add certain good qualities to steel, none of these combines with nitrogen, thus removing it from the metal, in the way titanium does. Its combination with nitrogen gas takes place with the evolution of heat, and it is the only undisputed example of the combustion of an element in nitrogen. When heated in oxygen it creates an instantaneous dazzling flame.

That oxygen and nitrogen are very injurious to steel and decrease its strength, wearing qualities, etc., is now a recognized fact, that these elements are present in larger quantities than has been previously supposed is also recognized. When titanium is added to the molten metal, it combines with these gases, which otherwise are liable to become occluded in the steel, and carries them off into the slag. These gases also form miniature bubbles that, when segregated, form holes large enough to be plainly seen. If segregated in large enough masses they form good-sized blow-holes.

Oxide forms when oxygen comes in contact with iron, and is present in very small black specks throughout the steel This oxide can only

be seen when the surface has been perfectly polished and magnified at least 1000 times. It is invariably found in steels that produce blisters when pickling, and this leads to the conclusion that the blisters are formed by the reduction of oxide by the hydrogen evolved during the pickling process. High-carbon steel rods that contain the same impurities occasionally fracture in the pickling bath, and doubtless the same pressure that blows a blister in mild steel will cause a rupture in hard steel.

Owing to the gaseous nature of both oxygen and nitrogen, it has been difficult to analyze steels for these contents. Some recent investigations, however, showed that the percentage of oxygen in some twenty-four samples of steel ranged from 0.021 to 0.046 per cent. These percentages may seem to be so extremely small that they could be ignored. But the amount of an element present, however, should not alone be considered, when judging its influence on steel; the combinations that the element forms should be taken into consideration. When mention is made of 0.05 per cent of sulphur, it is in reality the 0.13 per cent of manganese sulphide that affects the quality of the metal. Oxygen has only half the atomic weight of sulphur and is capable of forming larger quantities of compounds; therefore, it exerts a greater influence. Thus where 0.05 per cent of sulphur corresponds to 0.13 per cent of manganese sulphide, 0.05 per cent of oxygen corresponds to 0.22 per cent of ferrous oxide. This percentage is therefore high enough to very materially affect the qualities of steel.

Influence of Nitrogen on Steel

It has been shown by some recent investigations that, at first, an increase of nitrogen causes the toughness of steel to slightly increase, but reduces its ductility; each increase of nitrogen causes the elongation to rapidly diminish. Steel with 0.5 per cent carbon loses its ductility in the presence of 0.040 to 0.047 per cent of nitrogen. In a one per cent carbon steel, the elongation and contraction become nil when the nitrogen content reaches 0.030 to 0.035 per cent. In the softer steels, this happens when the nitrogen content reaches 0.050 to 0.065 per cent, and in the very soft steels, with about 0.08 per cent of nitrogen.

Open-hearth steel usually contains from 0.020 to 0.025 per cent of nitrogen; Bessemer steel from 0.018 to 0.062 per cent; and crucible steel runs from 0.010 to 0.015 per cent in nitrogen. Thus, a nitrogen content of at least 0.012 per cent must nearly always be reckoned with. Steels made in the resistance electric furnace are an exception to this, as they are practically free from nitrogen. Steels, however, that are made in the arc electric furnaces, in the presence of basic slags, are liable to contain injurious amounts of nitrogen.

Titanium has a very strong affinity for both oxygen and nitrogen; it forms with oxygen an oxide, and with nitrogen, a stable nitride that shows as tiny red crystals under the microscope. Both of these are then carried off into the slag and the quantity of slag that is lifted

from the molten metal is quite materially increased. The deoxidation of steel is usually accomplished with manganese and silicon, but these never remove the oxides as thoroughly as is desired. Titanium is a much more powerful deoxidizer than either or both of these, when added to steel at the time of tapping, it completes their unfinished work and reduces the oxygen and nitrogen to mere traces. If a greater amount of titanium is used than is needed to remove the oxides and nitrides, it will afterward attack the sulphur and phosphorus and if it does not remove them, it counteracts their injurious effects upon the steel. The phosphorus may be made to pass into the slag as phosphate of titanium by using special means. The reaction of titanium on the sulphur has a tendency to carry it off in the form of a sulphide or sulpho-cyanide of titanium Cupro-ammonium etching tests show the low sulphur and phosphorus content of titanium-treated steel The very energetic reaction of the titanium and nitrogen takes place at a temperature of about 1475 degrees F. The good effects of their union can easily be lessened by a careless shutting off of air, thus permitting the formation of titanium and nitrogen combinations that are of no value.

How easily nitrogen finds its way into steel is shown by a heat of Bessemer steel that had been over-blown three minutes. This was found to contain 0.032 per cent of nitrogen, whereas the normal steel contained only from 0.012 to 0.022 per cent. Another heat of Bessemer steel containing from 0.013 to 0.014 per cent of nitrogen was treated with one per cent of titanium and this reduced the nitrogen to from 0.004 to 0.005 per cent.

Method of Adding Titanium

When possible, it is always best to add the ferro-titanium to the steel while it is being tapped into the ladle, and after the ferro-manganese has been added It is lighter than iron and would not sink and disseminate if it were added near the top, hence, it should be shoveled in gradually while the steel is flowing into the ladle. Titanium-treated steels should be held in the ladle for from 5 to 15 minutes before pouring, in order to allow the titanium to do its work and scavenge out the oxygen and nitrogen. It is difficult to influence steel makers to hold the steel that long in the ladle, as without the titanium it would become chilled in a much shorter time Titanium, however, raises the temperature and the metal is in better condition for pouring after standing than before Owing to an accident, one ladle had to be held 20 minutes after tapping and adding the titanium and it was then found to be in better condition for teeming into ingots than the ordinary steel that is teemed as soon as the ladle is filled. This is a statement that is very difficult to make steel makers believe; but the evidence is very conclusive and can easily be obtained.

When commencing the use of titanium, one per cent should be added to the bath; this can gradually be reduced until the beneficial results obtained reach the high point and begin to diminish. In most

cases one-half of one per cent is all that can be made to benefit the metal. In manufacturing Bessemer steel rails, this latter percentage only increases their cost about $1.50 per ton. It is antagonistic to aluminum and the two should never be used together, for aluminum adds brittleness to steel, while titanium removes brittleness.

By removing the oxygen and nitrogen, titanium prevents the formation of blow-holes in steel. This is well illustrated by the two pieces shown in Fig. 4. The one containing blow-holes was cast without any titanium, while the piece without blow-holes was cast from the same metal after 0.5 per cent of titanium had been added. The reaction of the titanium raises the temperature of the bath and makes it more liquid by freeing it from the free oxide and slag. This allows the metal to subside in the mold while cooling and the pipe is smaller

Fig. 4. Blow-holes removed from Cast Iron by Titanium

and flatter. The metal invariably lies dead in the ingot molds and does not boil. By removing the occluded gases and slag from steel, titanium increases the density of the metal and retards any tendency towards segregation, thus making a much more homogeneous metal. It also increases the tensile strength, elastic limit, contraction, transverse strength and ductility of steel. It greatly improves its resistance to frictional or abrasive wear, and resistance to shock, torsional and impact strains.

Tests of Titanium Steel

One example of the ability of titanium steel to withstand torsional strains was obtained by twisting through seven complete revolutions a bar four feet long and one and one-eighth inch square; there was no sign of a fracture. The Brinell hardness test shows a titanium-treated steel to be softer than one not treated with titanium.

One recent test of some structural steel showed that before it was treated with titanium, it had a tensile strength of 67,000 pounds per square inch and an elastic limit of 42,000 pounds, the elongation being

24 per cent, and the contraction, 40 per cent. After this same metal had been treated with 0.50 per cent of titanium, the tensile strength was 77,120 pounds per square inch, the elastic limit, 51,750 pounds, the elongation, 25 per cent, and the contraction, 43 per cent

Another heat of steel that was rolled into billets and then into iron rods of slightly less than 1¼ inch diameter, had a tensile strength of 114,400 pounds per square inch, an elastic limit of 91,000 pounds per square inch, an elongation of 28 per cent, and a contraction of 52 per cent; ordinarily, 90,000 to 95,000 pounds per square inch is the tensile strength of this metal. This 20 per cent increase in tensile strength was doubtless due to the titanium removing the occluded gases and slag.

The resistance of titanium steel to abrasive or frictional wear is well shown by comparing the steel rails illustrated by Figs. 5 and 6. In

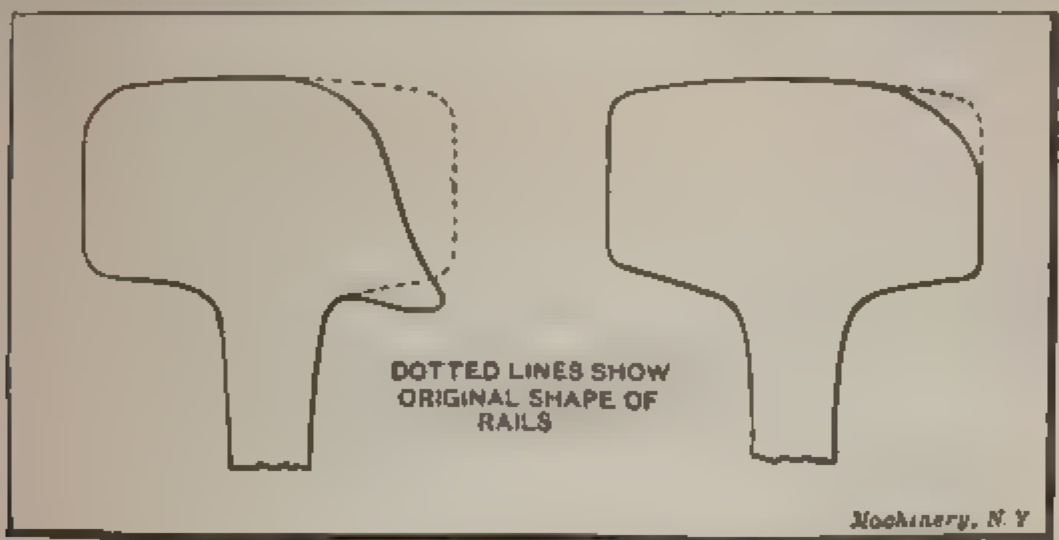

Fig. 5. Ordinary Bessemer Rail Showing Wear in Nine Months

Fig. 6. Titanium-treated Bessemer Rail Exposed to Same Amount of Wear

Fig. 5 is shown an ordinary Bessemer rail that was laid October 7, 1909, and measured July 8, 1910, to get the shape as shown and thus show the amount of wear. Fig 6 shows the shape of a titanium treated Bessemer rail that was laid next to that shown in Fig. 5 on the same date and measured on the same date. The ordinary Bessemer rail lost 7.03 pounds per yard during the 9-month wear, while the titanium treated rail only lost 1.39 pound per yard. Another method of testing for abrasive wear is performed with the machine shown in Fig. 7. This shows a section of a steel rail placed upon the top of a revolving plate, coated with abrasives, and held down by a lever. On the handle of this lever a block of iron of known weight is hung, as shown.

Titanium treated steels have recently been extensively tried for gears, plates, rolls, tires, castings, etc., and have almost invariably shown a reduction of brittleness and an increase of durability. One method of testing this is by the machine shown in Fig 8 In this, bar *A* is held in the machine and bent around a 1-, 2- or 3-inch center, as the case may be, located at *B*. Different sized centers are shown at *C*, *D* and *E*.

Fig. 7. Testing Rail Section for Abrasive Wear, in a Special Machine

Fig. 8. Machine for Making Bending Test on Titanium-steel Bars

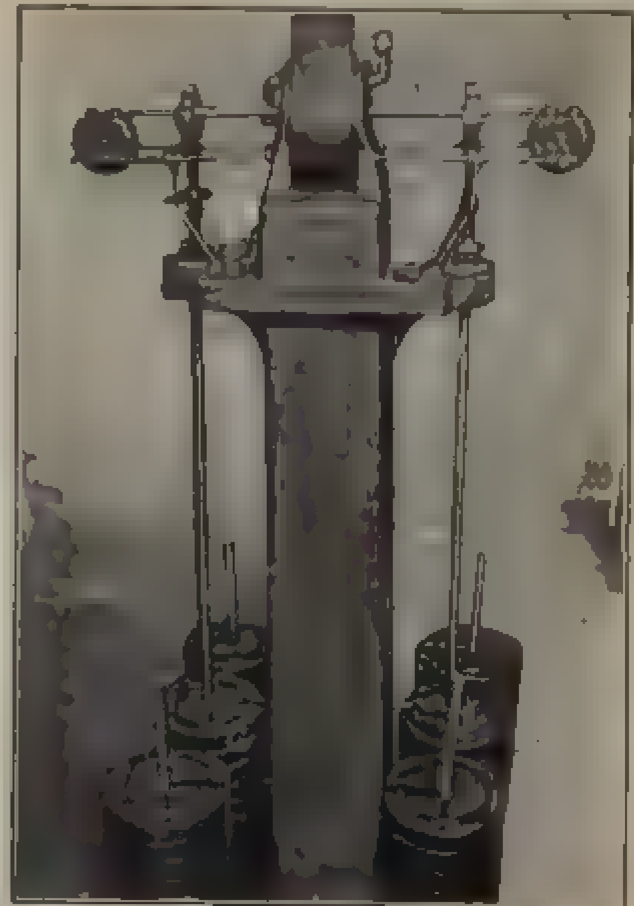

Fig. 9. Testing Endurance of Titanium Steel in a White-Souther Rotary Vibrational Testing Machine

A steel that contained 0.25 per cent of carbon, 0.30 per cent manganese, 0.40 per cent silicon, 0.04 per cent phosphorus, and 0.03 per cent of sulphur, would frequently crack in many directions when forged under a hammer at a bright red heat. When this same steel was treated with 0.030 per cent of titanium it worked down smoothly and evenly without a flaw. Good results might be obtained if the manganese and silicon were reduced by nearly 50 per cent

and the sulphur and phosphorus slightly increased, the effect of the titanium remaining practically the same as before.

The endurance of titanium treated steel has been well demonstrated by tests that were given it on the White-Souther rotary vibrational testing machine shown in Fig. 9. An open-hearth steel that contained 0.25 per cent carbon, 0.64 per cent manganese, 0.425 per cent silicon, 0.04 per cent phosphorus, and 0.035 per cent sulphur, withstood 2,660,000 revolutions at a fiber stress of 38,870 pounds. After this same steel had been treated with titanium, it was given 4,052,200 revolutions at the same fiber stress, namely, 38,870 pounds. The stress was then increased to 40,600 pounds and the piece stood 10,800,700

TABLE IX DROP TESTS OF RAILS

Number of Drop				
1	2	3	4	5
Deflection in Inches			Condition	
1.3	2.5	3.5	Straight	Broke
1.4	2.5	3.6	Straight	Broke
1.1	2.6	3.9	Straight	Broke
1.5	2.7	4.0	Bent other way	As before
1.5	2.1	4.1	Straight	Broke
1.5	2.1	4.1	Broke	....
1.4	2.7	3.1	Straight	Quite straight
1.4	2.7	4.1	Straight	Broke
1.4	2.2	3.4	Straight	Broke
1.5	2.7	3.9	Straight	Quite straight
1.6	2.9	4.1	Straight	Flange broke
1.6	3.1	4.4	Bent	Flange broke
1.6	3.1	4.2	Bent	Flange broke

Machinery

additional revolutions without a fracture. The fiber stress was again increased to 42,400 pounds and the piece given 1,918,600 more revolutions. The stress was increased a third time to 44,200 pounds and the piece was given an additional 1,006,300 revolutions before it broke. This was a total of 18,274,900 revolutions for the titanium steel, many of which were given it at an increase of fiber stress, as against 2,660,000 revolutions for the untreated steel.

For these tests a bar is placed in the machine as shown at *F*, and revolved by the belt and pulley while the weights located at *G* and *H* produce the fiber stress. As it is well known that iron is ductile in proportion to its purity, this increase in rotary vibrational strains can only be attributed to the purifying properties of the titanium which by removing the oxygen, nitrogen, etc., increases the cohesive force between the molecules and makes the steel more homogeneous. In increasing the ductility it does not soften the metal enough to weaken it, but on the contrary increases its strength. By removing the oc-

Fig 10 Testing Titanium Steel by subjecting it to Alternating Vibrational Strains

Fig. 11 Machine for giving Impact Tests to Steel

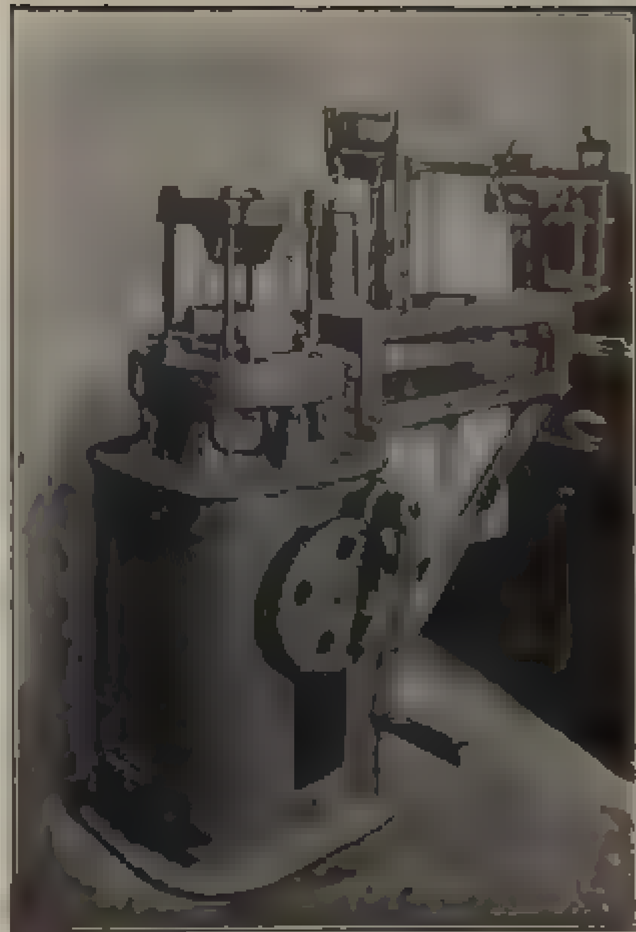

Fig 12 Machine for Testing the Strength of Titanium-treated Cast Iron

cluded gases and other impurities it also increases the resistance of the steel to corrosion.

Alternating vibrational strains are produced in the metal by the machine shown in Fig 10 In this the test piece is held at *I* while the part of the machine shown at *J* is rocked back and forth to alternately bend the samples ¼ inch either way from the vertical. This test has also given some very good results for titanium steel. Both

machines have a cyclometer attached to register the number of revolutions or alternations given the sample

Impact tests of the steel are made in the machine shown in Fig 11. In this, only the lower part of the machine could be shown, as it passes through the ceiling. The upper part is only a guide for the weight and, in this machine, extends 20 feet above the platen. The test piece is placed on platen *K*, and weight *L* is dropped on it, from a given height. When weight *L* strikes the test piece, the springs under platen *K* cause pointer *N* to register the foot-pounds of the blow, on dial *M*.

Some tests on titanium treated steel rails that were 85 pounds to the yard were conducted in a similar way. Rails were cut up into 3-foot 6-inch lengths, laid on supports three feet apart, and a weight

TABLE X. TURNING TESTS WITH TOOL STEEL

Number of Tool	Titanium Content, Per Cent	Depth of Cut in Inches	Width of Chip in Inches	Speed in Feet per Minute	Minutes Tool was Used	Condition of Tool at End
1	None	5/64	1/4	27	70 0	Blunt
2	None	3/64	1/4	27	71.5	Blunt
3	0 25	5/64	1/4	27	109 2	Blunt
4	0 35	3/64	1/4	27	117 3	Blunt
5	None	5/64	1/8	32	28 2	Blunt
6	None	1/64	1/8	32	42.8	Blunt
7	0 25	3/64	1/8	32	68 8	Blunt
8	0 35	3/64	1/8	32	76 4	Blunt
9	None	1/64	3/32	50	25 4	Blunt
10	None	1/64	3/32	50	70 6	Blunt
11	0 25	2/64	5/32	50	97.2	Blunt
12	0 35	1/64	3/32	50	138 2	Blunt

Machinery

of 2000 pounds dropped on them from a height of 17 feet. Three blows were given on the head and the deflection measured. Then the rail was turned over and the fourth and fifth blows were given on the base. Table IX gives the results of these tests

Titanium in Tool Steels

Titanium-treated steel can be made by the crucible process and only increases the cost of the metal $2.50 per ton when one per cent of titanium is used Some experiments and tests were conducted on titanium steels in Sheffield, England In these steels enough titanium was used to give 0 25 per cent and 0 35 per cent of the titanium in the finished steel An ordinary tool steel with a tensile strength of 127,000 pounds per square inch was used. Six lathe tools were made from it before the titanium was used The metal was then treated with titanium and six more tools made One tool with titanium and one without turned the same bar at the same time. Thus tools 1 and 3, 5 and 7, and 9 and 11 were used together and tools 2 and 4, 6 and 8, and 10 and 12 were used likewise. The tools were all given the same heat-treatment and the results that were obtained are shown in Table X.

In some experiments that were made by tool-steel makers in the Pittsburg district, it was found that if 0.50 per cent of titanium was retained in the steel, it would give cutting tools much greater durability and high-speed qualities. A special method is required, however, to retain any of the titanium in the steel, as its great affinity for oxygen and nitrogen causes it to go off into the slag. By removing the impurities, the titanium causes the metal to heat more slowly in the forge and also to retain the heat longer after it has been worked and become cold. This property of heating more slowly causes the cutting edge to last longer, as the temper is retained longer. The resistance to corrosion will also keep the tools from rusting, to a certain degree, when laid away.

As steel treated with titanium shows greater resistance to abrasive and frictional wear, it heats up more slowly from friction. Thus whether it be the tool or the work that is treated with titanium, the machine work can be performed more quickly, as the cutting speed can be increased; whether the tools be of the carbon or high-speed kind, makes no difference about increasing the speed. One instance of the slow heating of titanium treated metal was shown in some ingot molds that did not show red in the dark when filled with molten metal; whereas ordinary ingot molds filled at the same time and standing beside them, were distinctly red hot.

TABLE XI. TESTS OF GRAY IRON CASTINGS WITH AND WITHOUT TITANIUM

Without Titanium			With 0.5 Per Cent of Titanium		
Sample	Crushing Strength in Pounds	Deflection in Inches	Sample	Crushing Strength in Pounds	Deflection in Inches
1	2,240	0.10	1	3,050	0.09
2	2,260	0.10	2	3,140	0.10
3	2,010	0.09	3	3,150	0.10
4	1,840	0.08	4	3,230	0.10
5	1,970	0.08	5	2,850	0.10
6	2,150	0.10	6	2,990	0.09
Average	2,078	0.09	Average	3,068	0.10

Machinery

Steel castings that have been treated with titanium are more blue in color, freer from blow-holes and brittleness and heat up more slowly from cutting tools than ordinary steel castings; they can thus be machined more easily and rapidly. The No. 3 Government specifications for cast steel have been difficult to meet without resorting to several heat-treatments. They call for a tensile strength of 85,000 pounds per square inch, an elastic limit of 45,000 pounds per square inch, an elongation after rupture of 12 per cent, and a contraction of 18 per cent. By the use of 8 pounds of 10 to 15 per cent ferro-titanium to a ton of metal, the difficulties have been overcome by one foundry.

In fifteen heats before the titanium was used, the average tensile strength of castings after the first annealing was 81,633 pounds per square inch, the elastic limit was 47,233 pounds per square inch, the elongation, 15.1 per cent, and the contraction, 18.9 per cent. The fifteen heats after this, that contained titanium, produced castings with an average tensile strength of 91,533 pounds per square inch, an elastic limit of 50,000 pounds per square inch, an elongation of 19.2 per cent, and a contraction of 24.3 per cent. The steel that entered into the castings was made in a Tropenas converter, and was free from blowholes, homogeneous, and very uniform in its properties.

Very exhaustive tests have been made of the effect of titanium in cast iron and Table XI shows the comparison between gray iron as cast without titanium and with 0.5 per cent of titanium added. These tests were made in the machine shown in Fig. 12. The test bar is laid on the supports *O* and *P* while block *R* is forced down on it. The deflection and number of pounds required to break the piece are then measured. The transverse strength has been increased from 17 to 23 per cent by the use of titanium. It also increases the breaking stress, wearing qualities and hardness in the chill of cast iron; but it decreases the chilling effect.

CHAPTER VI

NATURAL ALLOY STEEL

Natural alloy steel is rapidly becoming an important material in the manufacturing field. It derives its name from the fact that the steel is manufactured from an ore in which nickel and chromium are alloyed by nature. While such ores have been known to exist for some time, it is only within the last decade that ores were discovered that had a uniform composition and existed in quantities sufficiently large to warrant their manufacture into steel.

Shortly after the Spanish-American War, such ore was discovered at Mayari and Moa in the Province of Oriente, in the eastern part of Cuba. These ores showed a remarkable uniformity of composition and covered some 25,000 acres on a plateau on the northern slope of a mountain range. In this place there is something like 1,000,000,000 tons of ore in sight, low in phosphorus and sulphur. The Pennsylvania Steel Co., Steelton, Pa., obtained the control of these ore beds and is, besides the Maryland Steel Co., Sparrows Point, Md., the only company manufacturing steel billets, blooms, bars, and miscellaneous forgings from the ore. The steel made by the Pennsylvania Steel Co. is known by the trade name "Mayari steel." Other companies purchase the billets, bars, etc., and roll and forge them into commercial shapes. The Philadelphia Steel & Forge Co., Philadelphia, Pa., is one of these firms; it has given the product the trade name "natural alloy steel," while the Carpenter Steel Co., Reading, Pa., calls it "Samson steel." Both of these latter firms make a specialty of rolling and forging shapes suitable for automobile parts, but they also manufacture the steel into bars and shapes that can be used for die-blocks, spindles, tools, and for numerous other purposes.

The various grades of steel into which this ore is manufactured contain from 1.00 to 1.50 per cent of nickel; from 0.20 to 0.70 per cent of chromium; from 0.30 to 1.50 per cent of carbon; and from 0.50 to 0.80 per cent of manganese; the silicon is kept below 0.20 per cent, and the phosphorus and sulphur below 0.04 per cent. These two latter elements, however, seldom reach 0.035 per cent, and a phosphorus content that is below 0.02 per cent is often obtained. The commercial stock is manufactured in two grades, one of which contains between 0.20 and 0.40 per cent of chromium, and the other between 0.40 and 0.70 per cent. Both of these can be obtained in any of the following carbon percentages: 0.15, 0.20, 0.25, 0.30, 0.35, 0.40, 0.45 and 0.50 per cent. Another brand that is used to a large extent for leaf springs, and also for other purposes, contains from 0.90 to 1.50 per cent of carbon and between 0.20 and 0.40 per cent of manganese, which is in accordance with the spring steel specifications of the Pennsylvania

Railroad Co. Titanium, vanadium and other purifying materials can be added to the steel if it is so desired, and thus further enhance the physical properties.

These natural alloy steels are carefully made by the open-hearth process and are, in the heat-treated condition, in every way the equal to 3½ per cent nickel steel. In some ways they are superior to this steel and especially is this true of the grade that contains the higher percentages of chromium, or when they are manufactured into parts that have a comparatively large sectional area. They are also cheaper

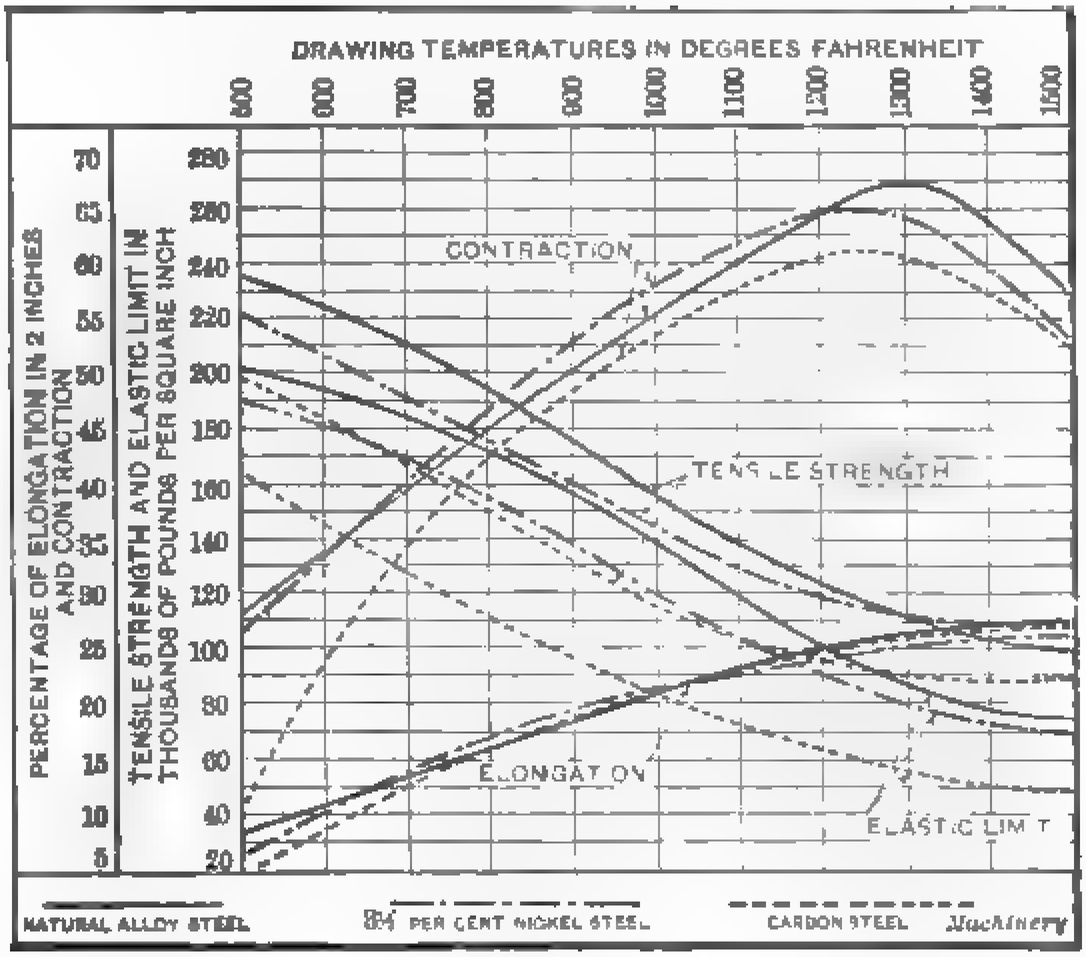

Fig. 13. Comparison of Characteristics of Natural Alloy, Nickel and Carbon Steels

than the nickel steels made by the same process, and in the billet form they are but little higher in price than the ordinary carbon steels. The high-grade and high-priced nickel-chromium steels are the only ones that are superior to the natural alloy steels in static strength, and this is largely due to the fact that they are usually made by the crucible process and contain a higher percentage of chromium, this being approximately 1.00 and 1.50 per cent in the two best brands.

Properties of Natural Alloy Steels

For comparing the static strength, a large number of tests were made with natural alloy, nickel and carbon steels that contained 0.40 per cent of carbon and were hardened at the critical point and then drawn at various temperatures between 500 and 1500 degrees F. The average results obtained from these three kinds of steels are shown

in Fig. 13. The steels compared all contained 0.40 per cent carbon. The natural alloy steel was quenched at 1520 degrees F.; the 3½ per cent nickel steel at 1500 degrees F.; and the carbon steel at 1530 degrees F. The average strength of each steel at a given drawing temperature can be obtained by following downward the line indicating the desired number of degrees, until it meets the curve of the tensile strength, elastic limit, elongation or contraction, according to which is to be found, and from this point following the horizontal line to the left, where the number of pounds per square inch, or the percentage, is recorded. In Table XII are shown the average elastic limit and ultimate strength as ascertained in some torsional tests made at the Pennsylvania State College. All heat-treated specimens were hardened and drawn to develop the best properties for driving shafts, axles, etc.

TABLE XII. AVERAGE FIBER STRESS IN POUNDS PER SQUARE INCH TORSIONAL TESTS MADE AT PENNSYLVANIA STATE COLLEGE

Kind of Steel		Natural Alloy Steel	3½ Per Cent Nickel Steel	Carbon Steel
Annealed	Elastic limit	41,500	40,800	32,500
	Ultimate strength	93,400	78,200	75,100
Heat-treated	Elastic limit	93,600	76,400	60,500
	Ultimate strength	130,200	108,000	102,400

Machinery

Much care has to be taken in manufacturing the ordinary nickel or nickel-chromium steels to prevent either of these elements from segregating in the bath or when teeming it into ingots. This is largely due to the fact that the nickel and chromium are additions and the bath must be heated to a comparatively high temperature just before teeming. In the natural alloy steel, however, the nickel and chromium are alloyed in the ore and are present in the bath from the time the melting operation starts until the finished steel is poured into ingots. Hence the bath does not have to be heated to any higher temperature at the time of tapping than do ordinary steels, and any tendency towards segregation is largely overcome. Thus, the elements are more uniformly distributed throughout the mass, and a homogeneous metal is obtained. When such elements segregate and the steel is rolled, they produce laminations in the metal which have a very injurious effect upon its strength, especially at right angles to the direction in which they are rolled.

Influence of Chromium

The extreme hardness produced by chromium makes it necessary to use comparatively small percentages in steels that are to be machined. When the chromium content reaches 2.00 per cent, the steel is very difficult to cut when cold, and when higher percentages are used, the

steel cannot be cut with any kind of cutting tools and must be ground to shape, this latter being an expensive method to pursue. Thus, in the high-grade nickel-chromium steels that are to be manufactured into parts of machines or instruments, the chromium content is usually about or below 1.50 per cent. Owing to the difficulty of working even this steel, however, many grades of steel have been made with a chromium content of 0.25, 0.50 and 0.75 per cent, and it is as a substitute for these grades that natural alloy steel can be used.

In steel, chromium gives the metal a hardness similar to that given by carbon, but to a lesser degree for the same percentage. It is a hardness, however, that makes the cohesion of the molecules much greater and thus greatly increases the static and dynamic properties. Chromium also greatly retards the formation of any grain or fiber, and thus makes the steel practically grainless. All of these effects of chromium upon steel cause it to increase its tensile strength, elastic limit, hardness, resistance to torsion, shocks, vibrations, or other stresses, and also increase its wearing qualitities and prolong its life.

Influence of Nickel

Nickel increases the ductility, toughness and resiliency of steel, and also increases its susceptibility to heat-treatment. It reduces the size of the crystalline structure and tends to prevent microscopic cracks that are liable to develop into larger cracks and produce ruptures. It was first added to steel to overcome the property of "sudden rupture" which is inherent in all carbon steels. It reduces the tendency of steels to become damaged by overheating in hardening, and shows its effect in the hardening operations by making the tensile strength and elastic limit two and three times that of the untreated, or annealed steel. Nickel raises the elastic ratio in steels, *i. e.*, the elastic limit is raised to a higher percentage of the tensile strength. This condition is always sought for in the better grades of steel.

The two elements mentioned, therefore, greatly enhance the value of natural alloy steel for the various parts of machinery that are subjected to severe stresses. This steel also resists corrosion much better than other steels, the sulphuric acid test showing that it corrodes from 10 to 20 per cent less than the low carbon and manganese, basic and open-hearth metals with nearly all of the impurities removed, which have been given such names as "pure ingot iron," "old-fashioned iron," "toncan metal," etc. While there are some that doubt whether this test agrees with the results obtained from exposure to actual weather conditions, it is generally conceded that steels containing nickel corrode less rapidly than carbon steels and wrought iron.

Working Alloy Steels

Natural alloy steel can be hammered, rolled, drop-forged, pressed, stamped, or machined with the same ease and at the same temperatures as carbon steel; no special precautions are necessary. The high-grade nickel-chromium steel (on the other hand, must be heated to

a white heat before being hammered, rolled, or drop-forged. The high temperature must also be maintained during the mechanical working, and if it falls very much, the steel must be reheated. Nickel steels must also be carefully handled when thus working them, and hence it will be seen that natural alloy steel is more cheaply worked into shape than other alloy steels. Natural alloy steel is similar to

TABLE XIII. EFFECT OF HEAT-TREATMENT ON FORGINGS OF NATURAL ALLOY STEELS

Per Cent of Carbon	Annealed				Heated to 1550° F. and Quenched in Water, Tempered at 1050° F.			
	Pounds per Sq. Inch		Per Cent		Pounds per Sq. Inch		Per Cent	
	Tensile Strength	Elastic Limit	Elongation	Contraction	Tensile Strength	Elastic Limit	Elongation	Contraction
0.30	89,500	57,500	28.0	51.9	106,500	76,000	21.0	51.9
0.40	88,500	56,000	29.0	51.9	112,500	83,000	23.0	59.8
0.50	119,500	68,000	18.0	37.1	135,000	107,000	16.5	46.2

Per Cent of Carbon	Heated to 1550° F. and Quenched in Water, Tempered at 1000° F.				Heated to 1550° F. and Quenched in Water, Tempered at 600° F.			
	Pounds per Sq. Inch		Per Cent		Pounds per Sq. Inch		Per Cent	
	Tensile Strength	Elastic Limit	Elongation	Contraction	Tensile Strength	Elastic Limit	Elongation	Contraction
0.30	131,000	114,000	17.5	51.9	193,000	177,000	8.5	30.7
0.40	130,500	118.500	18.5	51.9	209,000	188,000	10.5	37.1
0.50	155,000	138,500	14.0	43.0	252,000	232,000	7.0	24.0

other alloy steels, however, in that it is very difficult to weld by ordinary methods; parts that are to be submitted to great strains should not be welded together. Like other alloy steels it can be welded with more or less success by the various electric welding processes and machines that are on the market. The electric machines that squeeze the parts together are preferable, as these prevent the grain from becoming coarse, as it does when other methods are used. If the steel is hammered after welding, this will aid in refining the grain that has become coarse at the weld. By careful workmanship with the

electric process it is often possible to obtain from 70 to 80 per cent efficiency at the weld, whereas an efficiency of between 30 and 40 per cent is all that can be obtained by ordinary welding methods.

Natural alloy steels, like all other steels, will attain the highest strength only when properly heat-treated. In the untreated or annealed state, they show a tensile strength and elastic limit that is from 8000 to 10,000 pounds per square inch higher than carbon steels of the same carbon content, but when properly heat-treated they compare favorably with other alloy steels. Some figures that were obtained from annealed and heat-treated forgings are given in Table XIII.

Heat Treatment

The heat-treatment is practically the same as that given other steels. The hardening temperature may vary somewhat, but not to any great extent. The brands containing from 0.15 to 0.20 per cent carbon should be heated to 1500 degrees F. and quenched in brine to obtain the best results. Those with a carbon content between 0.30 and 0.50 per cent should be heated to 1550 degrees F. They can then be quenched in water as readily as carbon steels, although oil and special liquid compositions can be used for the quenching bath with equally good results. The temperature at which they are afterwards drawn, of course, varies with the kind of work that the finished piece would be called upon to perform.

When hardening steel, a cold piece should never be put in a highly heated furnace, as it is liable to crack. It should either be preheated to above 600 degrees F., or it should be put in a cold furnace and heated up slowly. It should soak in the heat at the hardening temperature long enough for the piece to heat clear to its center. The work should never lie directly on the hearth of the furnace, but should be raised sufficiently to allow the heat to attack it from all sides, and it should be supported in a way that will not allow it to sag, as hot steel is soft and pliable and likely to bend. The axis of the piece should be vertical when plunging it into the quenching bath to prevent unequal contraction in cooling. The work should never have sharp grooves, corners, or other features, that easily develop cracks when the steel is heated and quenched.

In drawing steel, a furnace should never be used that is hotter than the drawing temperature. It is difficult to judge the temperature that the work has attained in such a furnace and get within 50 degrees of the desired results. If the piece attains too high a temperature, it will be softer than that required, and if the drawing is too low, it will not be soft enough. With a tempering furnace held at the correct temperature, the work can be allowed to remain in it until it has absorbed the heat of the furnace and then accurate results can be obtained. A difference of 50 degrees in the drawing temperature is of much more importance than 50 degrees in the hardening temperature, and is more difficult to estimate.

Casehardening

Carbonizing or casehardening can be performed in any of the various ways that are now used for other steels. Pieces can be heated to a red heat and quenched in cyanide to give them a depth of casehardened surface of a few hundredths of an inch; or they can be packed in iron boxes with bone and charcoal, or other carbonizing materials, and then heated in furnaces for a time that is sufficient to give them a greater depth of penetration. Where the output would warrant it, however, the special furnaces that have been designed for carbonizing with gas would probably give the most uniform results, if the

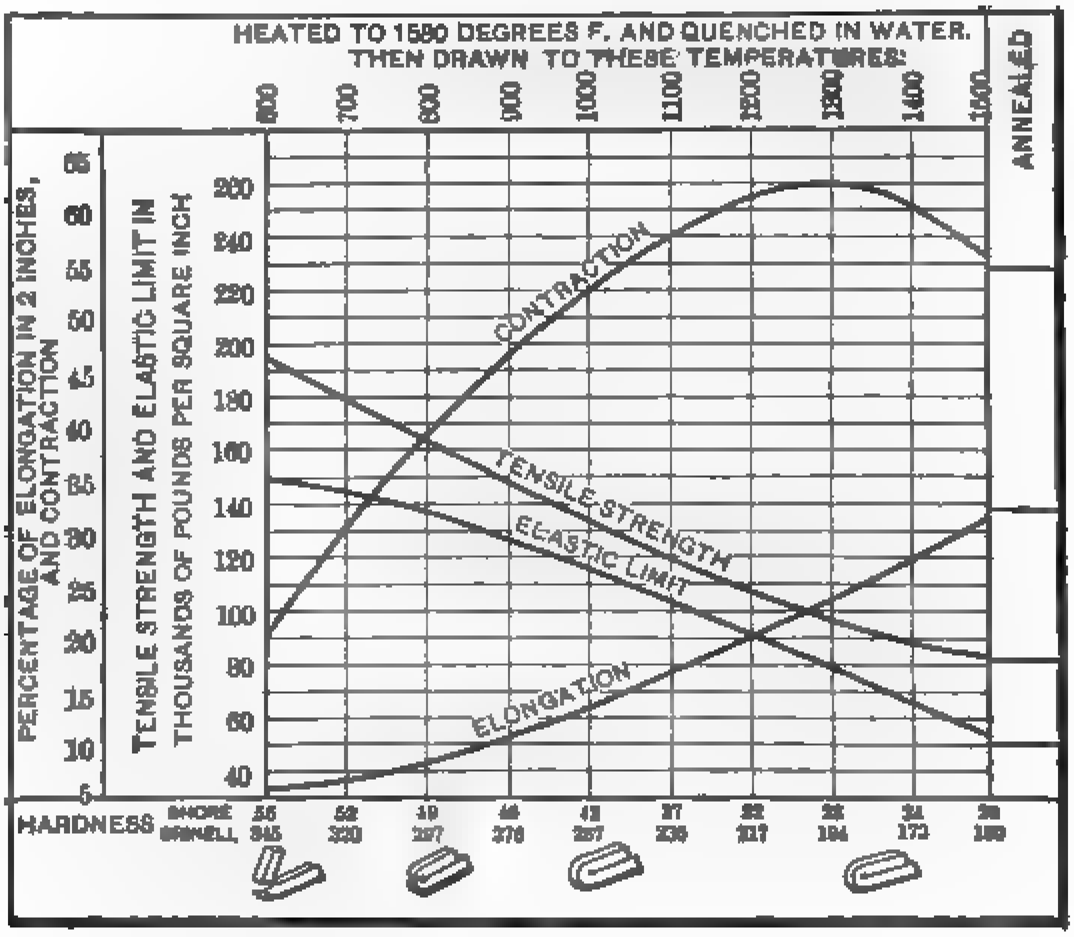

Fig. 14. Physical Properties of 0.30 Per Cent Carbon Natural Alloy Steel

work is properly done. This is also the cheaper method when large quantities are worked or handled.

In any case, however, the carbonizing mixtures should not contain over 15 per cent of moisture or 0.50 per cent sulphur. Moisture might cause a pitting of the steel which is liable to cause it to chip on the surface, while the sulphur soaks into the casehardened shell to a considerable extent. A carbonizing temperature of from 1750 to 1800 degrees F. can be used, and this will probably give the most rapid absorption and most uniform composition of the case. The time the steel is submitted to this temperature depends upon the depth of carbonized case desired.

After carbonizing, the work should be allowed to cool slowly until it becomes black in daylight. It should then be reheated to 1500 degrees F. and quenched in either oil or water. After this it should again be

reheated to 1350 degrees F. and again quenched in either oil or water. This double quenching gives much better results on all steels than does the ordinary practice of quenching directly from the carbonizing furnace and reheating but once to about 1375 degrees F. and quenching in oil.

In casehardened work, the core of the piece has a carbon content of about 0.20 per cent while the carbonized shell contains about 1.00 per cent. Thus, there are two steels of a different nature and these should be given different heat-treatments. In the double quenching,

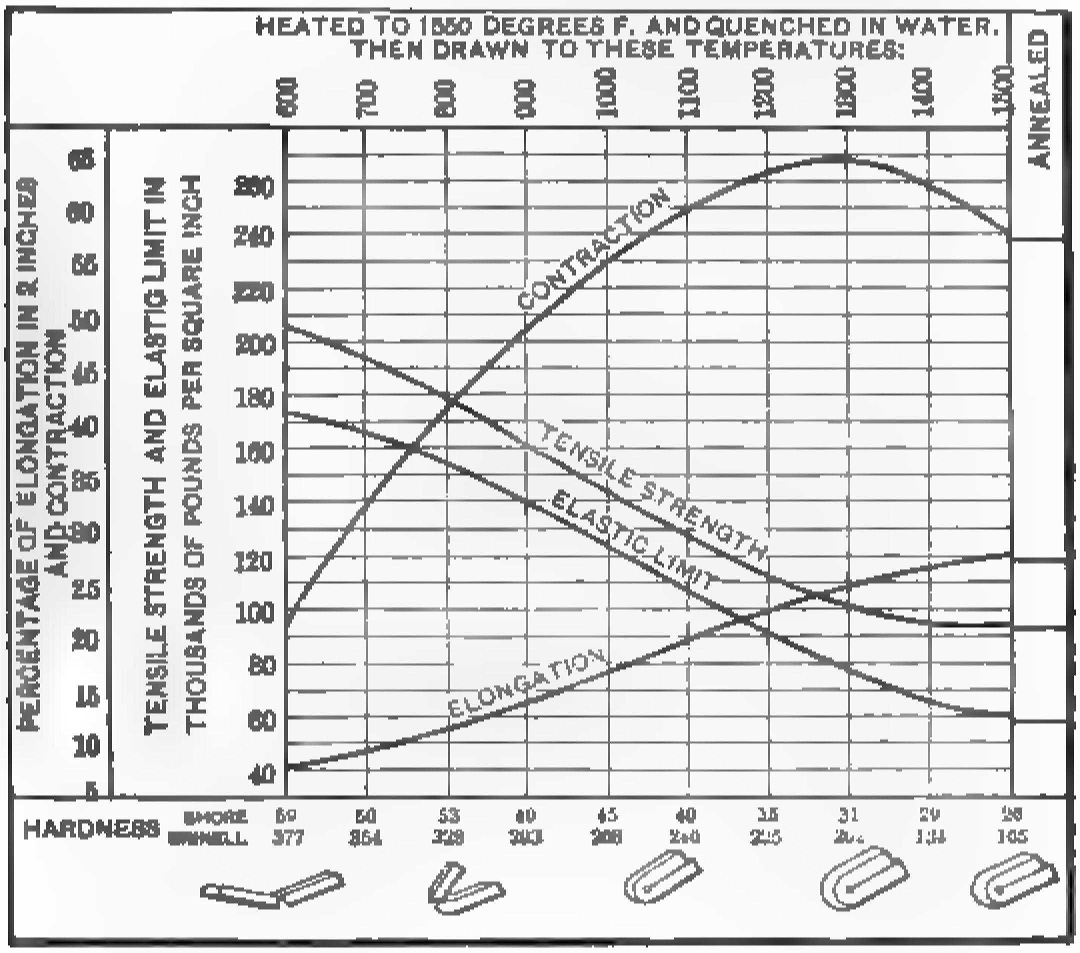

Fig. 15. Physical Properties of 0.80 Per Cent Carbon Natural Alloy Steel

the first heating and quenching hardens the core but overheats the case and makes it brittle. The second reheating restores the case to its fine-grain structure and also toughens the core, and the final quenching hardens the case.

Uses of Natural Alloy Steels

Natural alloy steels are largely used in the manufacture of automobile parts. A grade containing 0.15 per cent of carbon is often used for carbonized parts where the toughness of the core is of more importance than the strength of the steel or its ability to resist shocks. When parts are required to withstand severe shocks or strains and have a good wearing surface, steel containing 0.20 per cent of carbon is used. This grade responds more readily to heat-treatment. Thus speed-change gears, differential gears, drive gears, etc., are made from this steel. It is used without carbonizing where consider-

able toughness is required rather than strength, as in various structural parts. It is also used for cold rolling or cold pressing, and for such work as seamless tubes, small drop forgings, etc.

Tensile Strength, Elastic Limit, etc.

The tensile strength, elastic limit, elongation and contraction of this steel, as affected by various heat-treatment temperatures, are shown in Fig. 14. The vertical lines show the drawing temperatures which are marked in degrees at the top, while the horizontal lines represent the tensile strength and elastic limit and the percentage of elongation and contraction. Below the chart are given the hardness scales of the

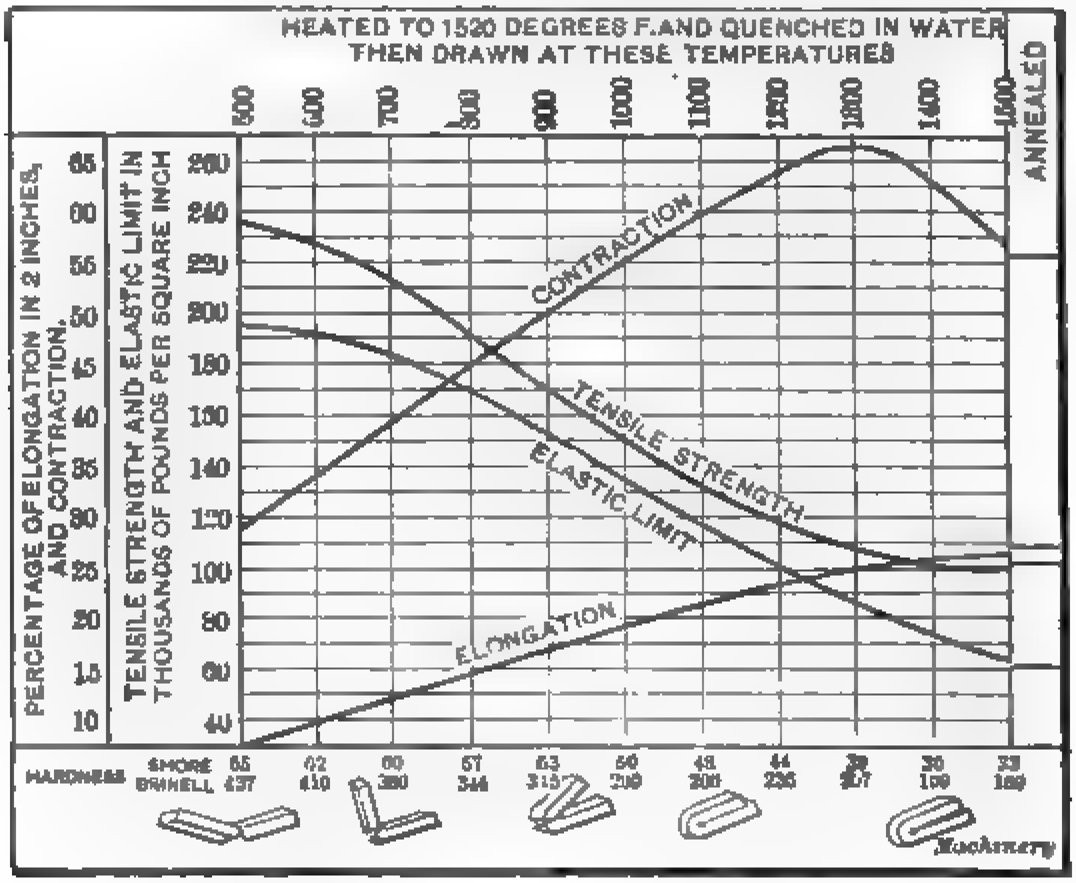

Fig. 16. Physical Properties of 0.40 Per Cent Carbon Natural Alloy Steel

steels, at these temperatures, taken from both the Shore and Brinell instruments. The cold-bend testing properties at the various temperatures are illustrated by the sketches below the chart.

From this diagram the heat-treatment that should be given this steel to obtain any of the properties that are within its range, can readily be ascertained. Thus if an elastic limit of 144,000 pounds per square inch, with a contraction of 31 per cent, is desired, the vertical line will show that the drawing temperature should be 700 degrees F. This would also give a tensile strength of about 177,000 pounds per square inch, and an elongation of about 6.5 per cent. The diagrams are based on 7/8-inch round stock; if larger pieces are used, the drawing temperature should be lowered.

The grade of steel containing 0.25 per cent carbon is usually employed for such parts as can be cold pressed, for instance, brake drums.

frame members, axle housings, etc. These parts require all the strength that can be obtained in combination with enough toughness to withstand the operation of bending into shape without developing cracks or checks. Steel 1¼ inch round, of this grade, when made into bolts, has a tensile strength of 106,000 pounds per square inch, an elastic limit of 87,500 pounds, an elongation of 26 per cent, and a contraction of 69.5 per cent.

The grade containing 0.30 per cent carbon is still harder and more applicable to heat-treated parts. Hence it is made into axles, connecting-rods, jack-shafts, drive shafts, and other parts that require considerable strength and at the same time a high degree of toughness. It is also used for drop-forgings, heavy forgings and numerous other things. The strength, hardness and cold bending properties of the 0.30 per cent natural alloy steels are shown in Fig. 15. That still greater strength can be obtained than shown in this chart was proved by a test made by one of the automobile manufacturers. The test bar was properly hardened and drawn at 600 degrees F.; the tensile strength was found to be 236,000 pounds per square inch, the elastic limit, 215,000 pounds, the elongation in two inches, 10.8 per cent, and the contraction, 36 per cent.

The grades containing 0.35 and 0.40 per cent carbon are used for spindles, rear axles, crankshafts, etc. From the 0.40 per cent grade are also made locomotive driving axles and heavy automobile truck axles, connecting-rods, piston-rods, steering knuckles, etc. The properties of the 0.40 per cent carbon grades are shown in Fig. 16. Some finished crankshafts, 2½ inches in diameter of the 0.35 per cent grade, had a tensile strength of 148,400 pounds per square inch, an elastic limit of 127,300 pounds, an elongation in two inches of 15.3 per cent, and a contraction of 53.8 per cent.

The 0.45 and 0.50 per cent carbon grades are used where extreme strength is needed in combination with considerable ductility. Thus, transmission gears that are to be heat-treated without carbonizing are usually made from this brand. The strength when heat-treated will, of course, be greater than shown in Fig. 16, but the ductility will be reduced.

At the present time there seems to be a tendency to "load" steels with alloying materials, and thus make them difficult to forge, weld, machine, or heat-treat, the results obtained do not always warrant the high prices of the finished parts. This natural alloy steel, however, is not overloaded with such alloying materials, but at the same time has properties that are well within the specifications for which many manufacturers are using much more expensive steels.

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CHAPTER I

PRINCIPLES OF COLD-HEADING

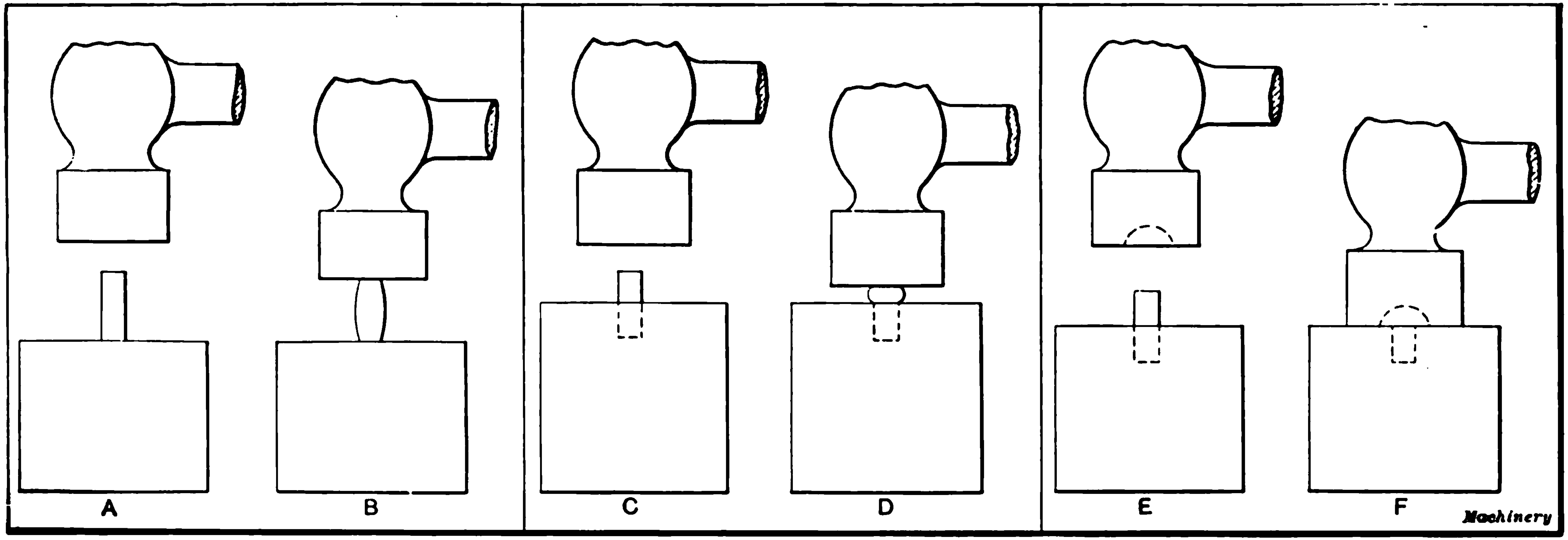
The operation of forming the heads of rivets, wood screw blanks, machine screw blanks, and similar products, by upsetting the ends of the wire lengths while cold, is known as cold-heading. The machines to which the wire is fed from a coil, and in which it is cut off and headed, are known as cold-headers. It is the purpose of this treatise to describe briefly the operation of various types of heading machines, to enumerate some of the limitations and possibilities of the different cold-heading machines and to give a general idea of the way in which the tools are planned and made for this class of machinery. No attempt will be made to cover the heading of hot stock such as is followed in making hot-formed bolts, as this type of machinery comes under the head of forging machinery, and is separately described in MACHINERY'S Reference Books No. 113, "Bolt, Nut and Rivet Forging," and No. 114, "Machine Forging."

Principles of Cold-heading

If we should cut off a piece of 3/8 inch diameter copper wire about 1 inch long, stand it on end on a hardened steel block, as shown at *A*, in Fig. 2, and strike it squarely on top with a heavy hammer, we would upset the piece as a result of the blow, causing it to bulge considerably at the center, the amount depending upon the force of the blow, leaving it with an appearance as indicated at *B*, Fig. 2. Continuing our experiments, if we take another 3/8-inch piece of copper wire, 1 inch long, as before, and drop it into a 3/8-inch hole in a hardened steel block, allowing a section ½ inch long to extend above the surface of the block, as at *C*, Fig. 3, and strike the end of this piece a square blow with the same hammer, the piece will assume about the appearance indicated at *D*, in Fig. 3 The projecting section will be bulged as before, but the part of the blank remaining within the block must necessarily retain its original shape, as it is confined in all directions. Continuing our experiments still further, if we take a new blank of the same dimensions and insert it in the same block as before, but in place of the flat ended hammer we use one with a cup-shaped depression turned in its face, as shown at *E*, Fig. 4, and strike the blank a hard blow squarely upon the projecting end, the end of the wire will necessarily take on the appearance indicated at *F*, Fig. 4. The blank *must* assume this shape because the part under the head is confined within the lower block and the head section is guided in its bulging by the cup-shaped depression in the hammer with which the blow is struck.

These three simple experiments outline the principles involved in cold-heading In all cold heading operat confined at

Fig. 1. Miscellaneous Samples of Cold-heading made on E. J. Manville Machines



Figs. 2, 3 and 4. Illustration of Principles of Cold-heading

bottom and sides, leaving the metal which is to com- the head projecting, so that it may be upset and d by the punch of the heading machine. In cold- g, the fundamental point to be remembered is that, ressure, the wire stock will always flow in the direc- the least resistance.

Early History of Cold-heading Machinery

use of hand-formed rivets dates back to the ancient ians, but this article must be confined to the machines and tools used for automatically producing rivets and screw blanks. The first instance we find of cold-heading by machinery was in England, about 1760, when two brothers, John and William Wyatt, designed and built a machine for heading wood screw blanks. In America, there is no doubt that Josiah Gilbert Pierson's cold-header, patented March 23, 1794, was the first machine of its kind, although the patents were destroyed when the patent office was burned early in the last century. Pierson's factory was first on the site of the present New York Produce Exchange, but later

he moved to Ramapo, N. Y. His heading machine was a massive affair, with a heavy framework anchored to the floor. A large flywheel was provided, and the machine was operated on the now familiar toggle principle. In 1838, the Eagle Screw Co., of Providence, R. I., was started by William G. Angell, and its earliest machine was what is known today as the old Eagle header. At the factory of the American Screw Co., Providence, R. I., this type of machine is used today on certain classes of work. Mr. Benjamin Thurston, superintendent of the American Screw Co., states that in the early days of cold-heading each machine was mounted upon the ends of long posts which ran through the floor down to a solid ground foundation.

An Old Type of Header

In Fig. 5 is shown one of the earliest cold-heading machines now in existence, and while it has long ago out-lived its usefulness, it is inter-

Fig. 5. An Old Type of Header

esting to compare it with modern heading machines. This machine was designed by W. E. Ward and built by Russell, Burdsall & Ward, of Port Chester, N. Y., at some time prior to 1856. The line engraving Fig. 6 gives an idea of the general principles upon which this machine operated, from which it will be seen that the operation of the punch was effected by means of toggle mechanism actuated by a cam on the lower shaft of the machine. The vertical cross-section through the dies is indicated at the left. As the machine was of the open-die type, the lower die was actuated by another cam. Two extremely heavy rods extended the length of the sides, as shown in the engraving, Fig. 5, and in section in the illustration, Fig. 6. These served to tie the machine together, enabling it to better withstand the heading operation. The output of this machine, which was used for making stove bolts $\frac{1}{4}$ to $\frac{3}{8}$ inch in size, was about 30,000 headed pieces per day of eleven hours.

Operating Principle of Modern Heading Machines

Practically all modern heading machines operate upon the same general *principle*, although there are many modifications and features

which each maker considers best. By referring to Fig. 7, which shows the plan view of a modern single-blow solid-die heading machine, it will be seen that there is a heavy framework *A*, at one end of which is located the driving shaft *B*, rotated by a driving wheel at the right-hand side; at the other end is located the die-block *C*. Between the sides of the heavy framework is a movable ram *D* which serves to actuate the heading punch *E*. The wire, which is indicated at *F*, enters the machine through feed rolls *G* and thence through the framework of the machine, passing through the cut-off quill *H*. At the left-hand side of the machine is supported the bracket *I*, in which slide *J* may be reciprocated by means of a crank motion from the main driving shaft. Slide *J* contains a cam groove in which roll *K* is fitted, and as roll *K* is mounted upon the cross-slide *L*, it will be seen that a lateral motion is thus imparted to the cut-off knife *M*, located on the

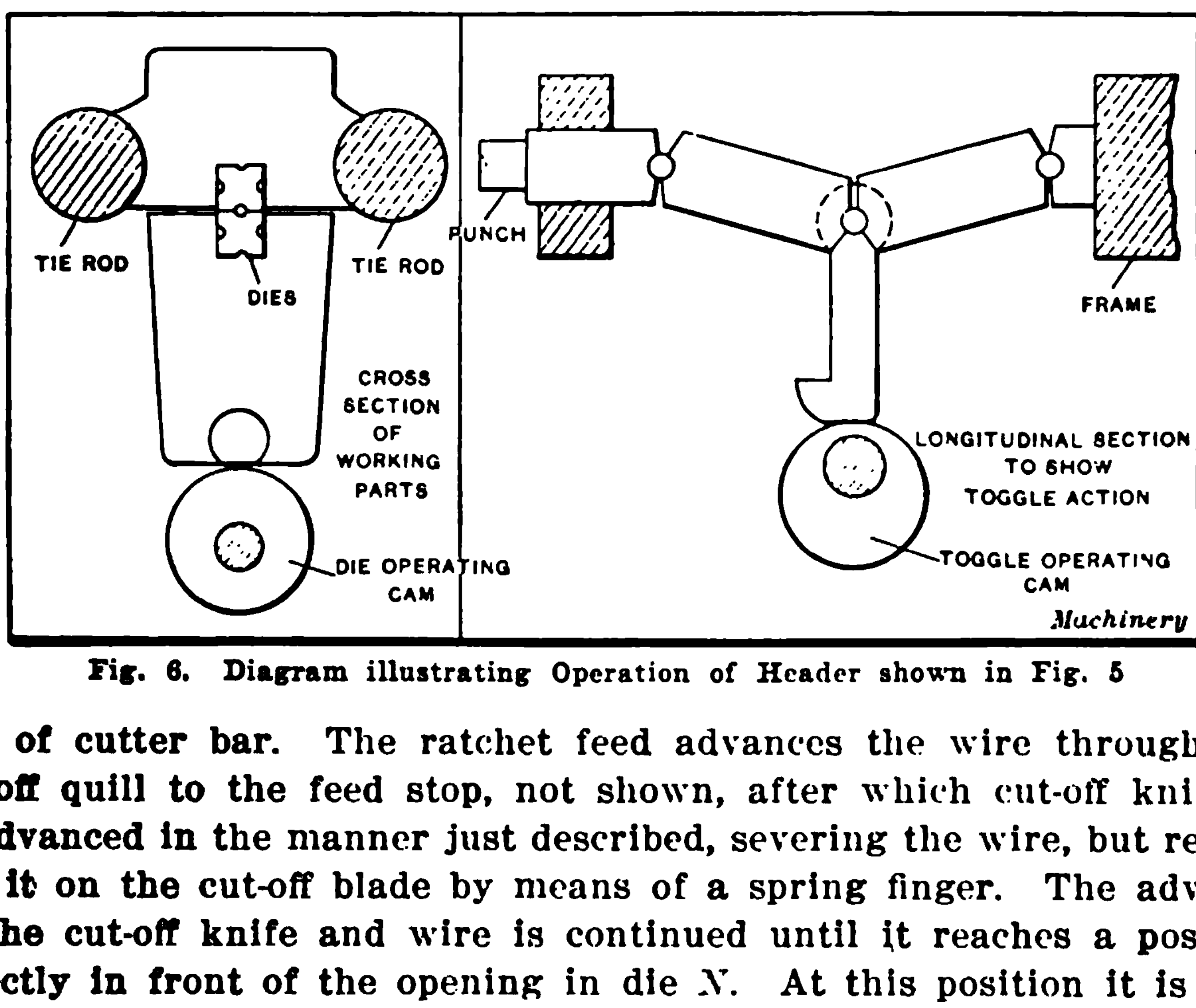


Fig. 6. Diagram illustrating Operation of Header shown in Fig. 5

end of cutter bar. The ratchet feed advances the wire through the cut-off quill to the feed stop, not shown, after which cut-off knife *M* is advanced in the manner just described, severing the wire, but retaining it on the cut-off blade by means of a spring finger. The advance of the cut-off knife and wire is continued until it reaches a position directly in front of the opening in die *N*. At this position it is held stationary long enough for punch *E* to begin to push it into the die, at which time the cut-off knife retreats and allows the punch *E* to continue its work by pushing the blank to the bottom of the die cavity, afterward upsetting the projecting part of the wire to form the head. The wire blank *F*, when pushed into the die, is prevented from passing too far by a backing pin *O*. After the piece has been headed, the backing pin is advanced by ejecting mechanism operated by lever *P*, which receives its motion from a crank on the right side of the machine connected to the main driving shaft. This, briefly stated, is the general principle upon which all modern heading machines of the single-blow solid-die type operate.

There are two distinct principles employed for recipro movable ram of a cold-header. These are the crank or

gle principle. In the machine just described and illustrated in Fi
notion is transmitted to the ram by means of an eccentric upon th

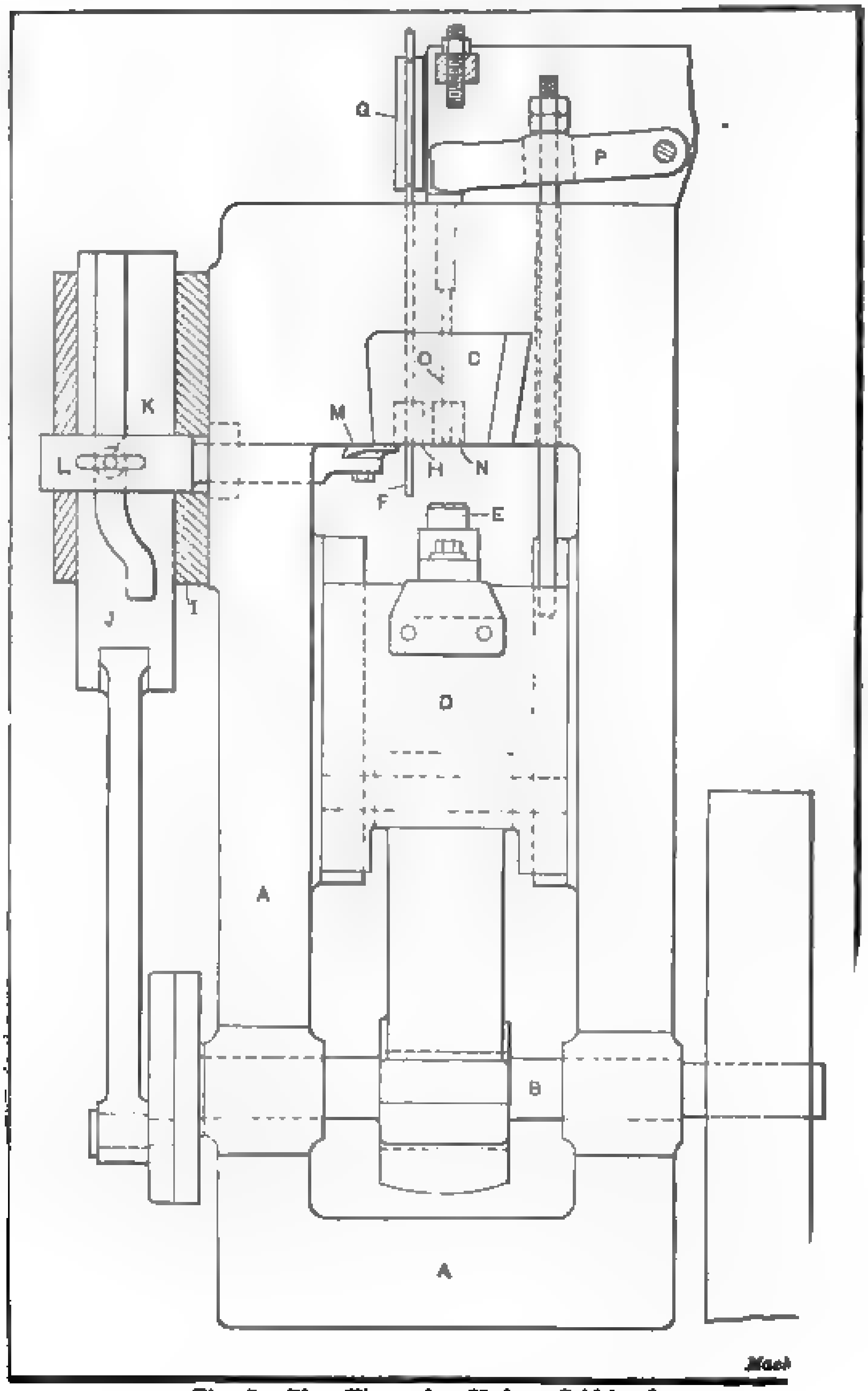


Fig. 7. Plan View of a Modern Cold-header

driving shaft, the eccentric, of course, being a modificati
crank principle By referring to the diagram Fig. 8, it w
that in the crank-operated header the length of the strol
to the diameter of the crankpin circle, and that one strok

plished in each revolution of the driving shaft from which the crank is operated.

The crank principle is employed on most single-stroke machines and by one manufacturer for double-stroke machines as well. On double-stroke cold-headers of the crank-operated type, it will be seen that the crankshaft must make two revolutions to secure the two strokes, and

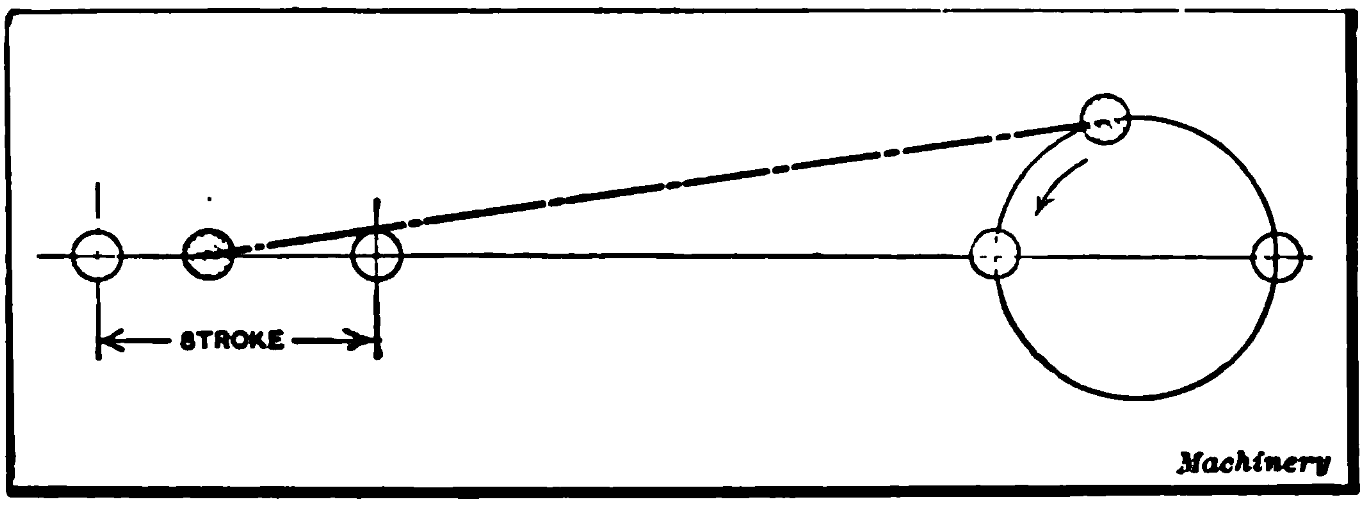


Fig. 8. Diagram to illustrate Operation of Crank Headers

these two strokes will be of equal length. The blow secured by the crank-operated header is of a quick punching character rather than a gradual squeezing operation, and exponents of crank-operated headers consider this feature to be of great importance.

Toggle-operated Headers

The other principle upon which cold-headers operate is the toggle principle, of which there are several variations. The common type of

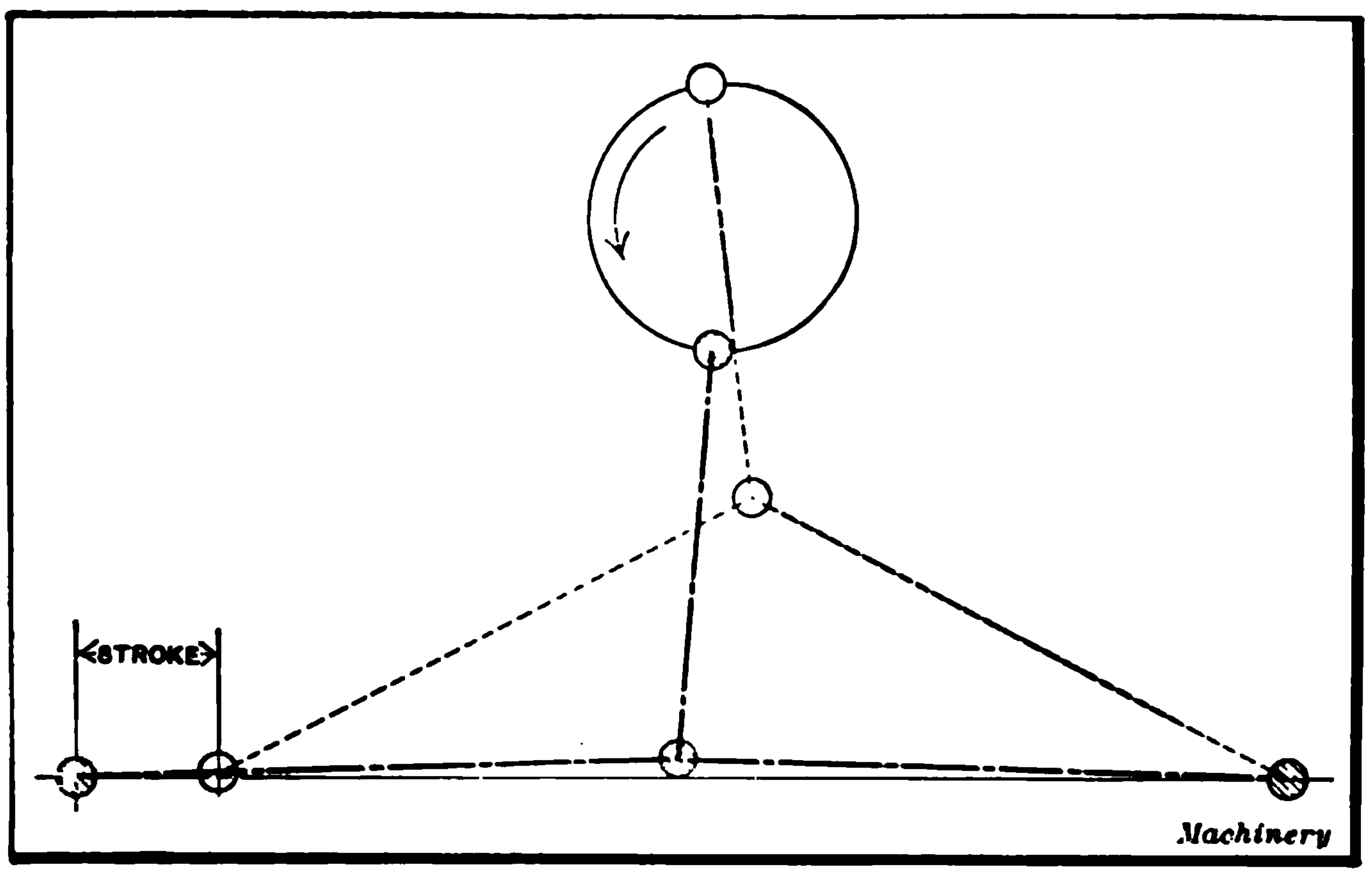


Fig. 9. Diagram to illustrate Operation of Toggle Headers of Two-cycle Type

toggle action is that shown in Fig. 9, in which the toggle is straightened by a crank-actuated link, which brings the arms of the toggle to a straight line once during each revolution of the crankshaft. This, of course, gives one stroke of the ram to [illegible] e crank-shaft, but the blow obtained is of a gr[illegible] especi-ally at the ends of t[illegible] stroke whe[illegible]

is being done. This type of toggle mechanism is known as the two-cycle type, two revolutions of the crankshaft being necessary to complete a "two-blow" rivet. Another type of toggle operating mechanism which is extensively used on the double-stroke machines is illustrated in Fig. 10, from which it will be seen that two blows are struck at each revolution of the crankshaft which operates the arms of the toggle. As this type of machine makes a two-blow rivet in one revolution, it is termed a "one-cycle" machine. The chief difference between the two-cycle type of toggle action and the one-cycle type lies in the fact that in the two-cycle mechanism the toggle is straightened when

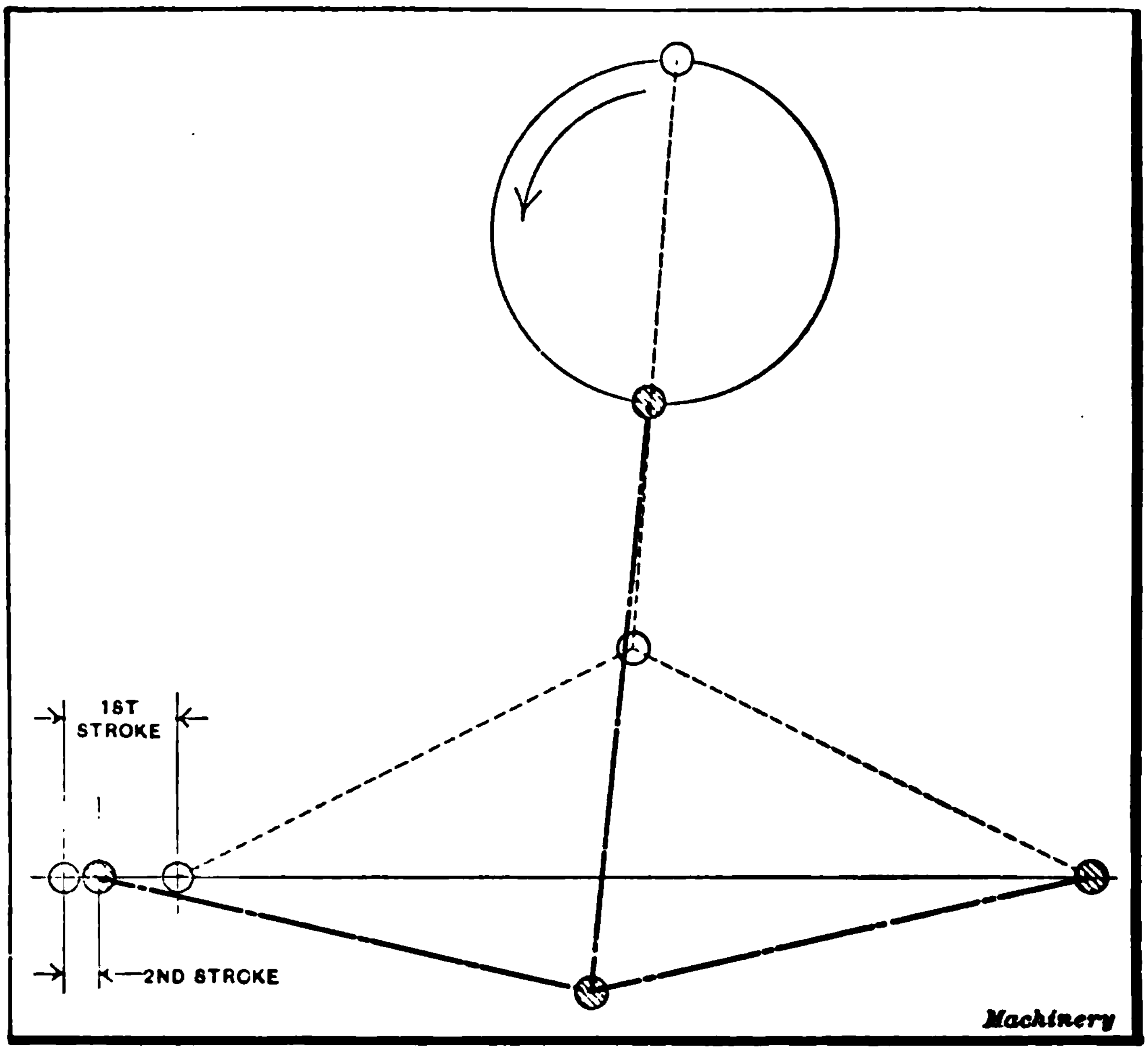


Fig. 10. Diagram to illustrate Operation of Toggle Headers of One-cycle Type

the extreme of the crank motion is reached, but in the one-cycle mechanism it is straightened midway of the extreme distance of the crank, so that in the latter machine two blows are secured during one revolution of the crankshaft. The two strokes may be of equal length; the first stroke may be the longer, or *vice versa*, by varying the distance between the crankshaft and the line of the straightened toggle. In Fig. 10, the first blow is the long blow as the toggle is pushed down to the straightening point. As the toggle is drawn further above the straightening line than it was below, the second blow will be the short one, as indicated.

Double-stroke Cold-headers

In describing the header illustrated in Fig. 7, it was stated that this was a single-stroke machine as contrasted with a machine for striking

two blows on each piece. A great many jobs of heading, however, cannot be adequately handled on a single-stroke machine, as there is too much metal to be upset in the head. When the amount of metal to be put into the head exceeds two and one half diameters of the wire in length, it is necessary to employ a double-stroke machine. The double-stroke machine operates in practically the same way as that shown in Fig. 7, except that it strikes two blows in rapid succession upon the wire blank before it is ejected. The preliminary blow is known as the coning blow; in this the wire is partly upset and prepared for the second blow which finishes the head. The two punches are "slidably" held on the ram, and the mechanism for changing the positions of the dies for the two blows is called the rise-and-fall motion. While there are several different means of securing this motion,

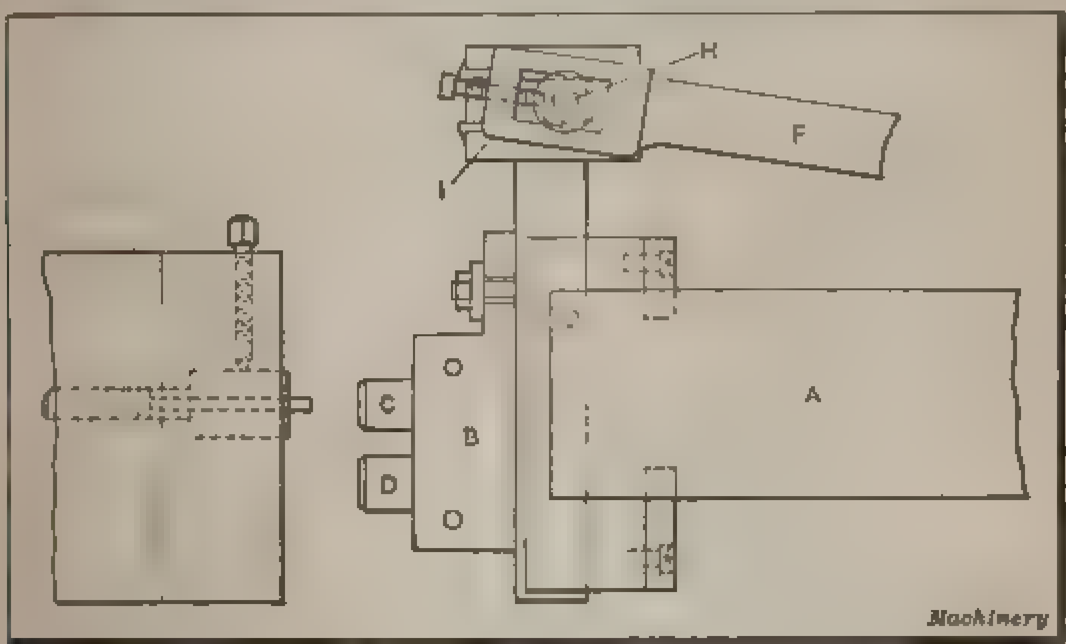


Fig. 11. Mechanism for operating Ingraham Rise-and-fall Motion

the Ingraham rise-and-fall motion used on Blake & Johnson cold headers is typical. By referring to the line illustration Fig. 11, which shows a side elevation of the principal parts, in connection with the halftone illustrations Figs. 12 and 13, the operation of this device can be readily followed. Upon the end of ram *A*, the die-holding slide *B* is secured. This slide is free to move vertically so that upper punch *C* or lower punch *D* may be operated in alignment with the stationary die. In Figs. 12 and 13, these dies are not shown. Pivoted upon bracket *E*, which is bolted to the left side of the frame, as shown in Figs. 12 and 13, is the lever *F* which controls the rise-and-fall movement of the punch slide. This lever is actuated by a cam upon the driving shaft of the machine, as indicated at *G*, Figs. 12 and 13. At the opposite end of lever *F*, a bearing pin *H* is adjustably mounted, being free to slide in the ways provided in section *I* of the punch holding slide. Thus by having cam *G* of the proper shape, the rise and fall of punch-holding slide *B* may be so timed that at the time of the position of the first blow, punch *C* will be in line with the die, and at the time of the position of the second blow, punch *D* will be in line with the

It is obvious that on double-stroke machines, the wire feeding, ... ff and ejecting mechanism must be geared to agree with every ... ed stroke of the ram

Triple-stroke Headers and Reheaders

In addition to single- and double-stroke machines, triple-stroke ... aders are sometimes used where the amount of metal to be dis-

Fig. 18. Plan View of Blake & Johnson Double-stroke Solid-die Header

placed is more than can be effected with two blows. Triple-stroke headers are similar in action to other headers, except that three blows are struck Two blows, however, will usually upset the metal of most heads to a point of crystallization so that except in special instances the use of a third blow would be of no advantage, because the blanks would require annealing before a third blow could be struck Many heading jobs require two distinct operations to perform the work, usually on account of the shape of the pieces. For this

purpose the work is carried as far as possible with an ordinary single- or double-stroke header, after which the pieces are annealed and completed in a reheader. By means of an automatic hopper feed the partly formed pieces are placed in the heading dies and the subsequent operations performed. Reheaders are made with strike one, two or three blows.

Open-die Machines

Thus far we have only described single- and double-stroke machines of the solid-die type, but for handling work in which the length of

Fig. 13. Phantom View to illustrate Operation of Ingraham Rise-and-fall Machine

the pieces under the head exceeds nine or ten diameters of the wire, it is necessary to employ dies which open longitudinally to make ejection of the work possible. The heading operation upsets the metal of the blank for its entire length in addition to the upsetting of the head, so that the metal of the shank is squeezed out against the sides of the die. In the case of a solid die this upsetting of the metal in the shank makes the resistance to ejection too great, especially when the work has a very long shank.

Cold-headers employing open dies require die-operating mechanism of an entirely different character from that which is used on solid

die machines. By referring to Figs. 14 and 15, the operation of the dies of a machine of this type may be followed. Referring to Fig. 14, the framework of the header is shown at *A*, the ram at *B*, and the

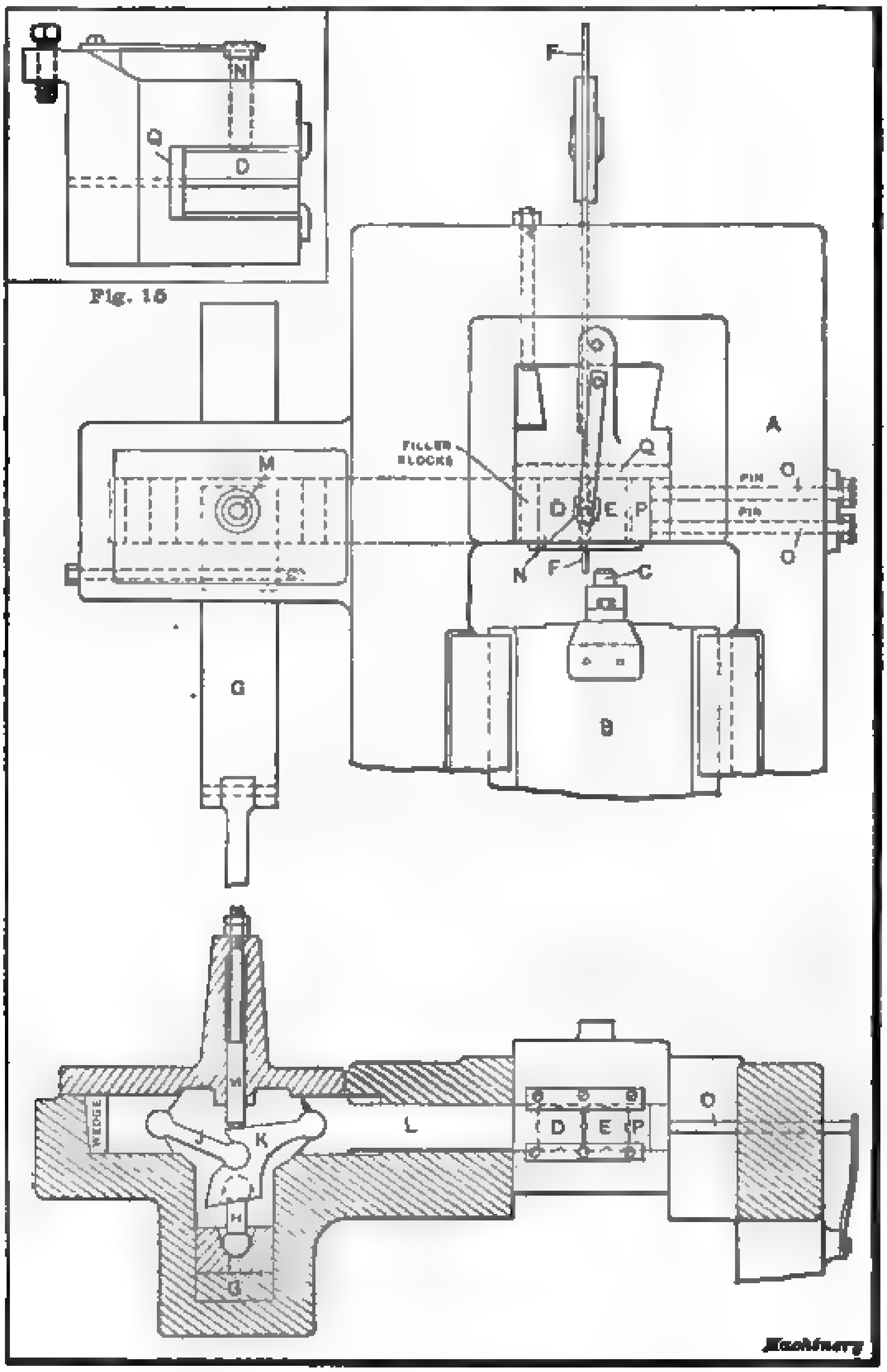


Fig. 14. Construction of Die-operating Mechanism for Open-die Headers.
Fig. 15. Side Elevation of Dies and Spring Pin

punch at *C*. The two halves which constitute the dies are shown at *D* and *E*. The wire, which is indicated at *F*, runs through straightening rolls of the usual type through the framework of the machine as well as the die-holding block, and thence through the dies them-

selves. In feeding, the wire is run out against a stop, not shown, and is cut off by the movement of the two halves of the die in unison toward the right, which also brings the wire blank over into line with the heading punch C. Different makers of cold-headers use different methods for moving the die-blocks, and one of these constructions is here illustrated. The action of this mechanism is best shown by the sectional view in Fig. 14. A flat cam G is reciprocated by a crank connection to the driving shaft of the machine. When this flat cam is pushed in, it raises the toggle of which arms H and I are members. This action tends to straighten another toggle composed of arms J and K, and in straightening the latter toggle, slide L is made to push die-halves D and E laterally, thus severing the wire and moving it into the heading position. A spring pin M assists in returning the toggle mechanism for another operation. By referring to the sectional illustration, it will be seen that the corners of the two halves of the die are chamfered. A wedge pin N, more clearly shown in the smaller illustration, Fig. 15, fits into this chamfered opening at the parting line, and by means of a flat spring which presses downward upon the wedge pin, it tends to force the dies apart whenever lateral pressure is removed. This, of course, facilitates the ejection of the headed piece, which takes place when the new length of wire comes forward. Similarly, two spring pins O are provided which press against a filler block P on the opposite side from the die-operating plunger L. These serve to return the dies to the cut-off position after the piece has been headed.

In the heading position the rear end of the wire blank is backed up by backing plate Q, which is of hardened steel, so that the rivet or screw blank is effectively contained while being headed. From this construction it will be seen that the length of the dies must be the exact length of a headed rivet or screw blank measured under the head.

CHAPTER II

COLD-HEADING MACHINES AND OPERATIONS

In the preceding chapter the principles of cold-heading, together with its early history and a general outline of the machines employed, were given. In this chapter a brief description of representative machines of each of the principal types of cold-headers will be given, with statements of the possibilities and limitations of the work which may be done on each of these classes of machines. From the preceding pages it will be gathered that all cold-headers, whether of the crank- or toggle-operated types may be divided into single- and double-stroke machines on the one hand, and into solid- and open-die machines on the other hand. When we consider that single-stroke machines may be of solid- or open-die types, and double-stroke machines of solid- or open-die types either crank- or toggle-operated, and that the toggle-operated machines may be either one- or two-cycle type, it will be seen that to describe each of the combinations that are found in cold-heading machinery would be an endless task. In addition to the above-mentioned class of heading machinery, there are reheaders of single-, double- and triple-strokes; and in the special industries like that of tack- and nail-making the machines are still more special, but by describing the most common of the machines in general use an adequate idea of cold-heading machinery will be given, as the general operating principles are similar.

E. J. Manville Single-stroke Solid-die Cold-header

The single-stroke solid-die header is undoubtedly the simplest of all, and for that reason has been selected for the initial description. This machine is built in six sizes; the smallest size handles wire up to 1/8 inch diameter and the largest, which is the machine illustrated in Fig. 16, handles wire up to 1/2 inch diameter. The frame is of very heavy section and the crankshaft, which is of large diameter, is made of forged nickel steel. The bushings which support this crankshaft have their bearings close to each side of the crankpin so that there is little danger of bending the crankshaft by the heavy work required in cold-heading. The wire is fed in from the front of the machine through the usual type of grooved roll and is lubricated by a reservoir below the lower feed-roll. The cut-off is operated from the side in the manner described in the previous chapter, and on this machine a safety connection is provided between the crank and cut-off cam slide. This is in the form of a shear pin so that if excessive load is placed upon the cut-off knife the machine will stop without doing damage other than shearing the safety pin. A patented form of cut-off knife is employed so that the blank will be held rigidly while being sheared and thus cut squarely. This is an essential feature on single-stroke machines, for as there is no preliminary or coning blow to centralize the stock, it

Fig. 16. Single-stroke Solid-die Cold-header—E. J. Manville Make

Fig. 17 Double-stroke Solid-die Cold header—Blake & John-

must go to the dies in good condition after being cut off. The balance wheel is very heavy in design, and as it is essential that a heading machine be stopped at some point other than the center, a foot brake, shown in Fig. 16, is provided, so that the wheel may be stopped at any desired point in its revolution.

Single-stroke headers of the open-die type are not very largely used except in the wood-screw industry. The main point of difference between this type of machine and the one previously described is the die-operating mechanism, and this mechanism was described in general in the preceding chapter.

Blake & Johnson Double-stroke Solid-die Cold-header

Fig. 17 illustrates a double-stroke solid-die header made by the Blake & Johnson Co. of Waterbury, Conn. This machine is one of the latest of its class and has some radical differences which are worthy of description. This is the first header to be made with a pan or tray between the frame and legs. In addition to catching dripping oil and odd ends of wire it furnishes a shelf for catching the finished work. This form of construction results in a more rigid machine than any of those types where long slender legs are employed. By observing the cut-off cam-slide mechanism at the center of Fig. 17, it will be seen that the cam groove is cut in the face of a segment rather than in a slide. This segment is pivoted on a stud as shown, and it is claimed that less power is required for its operation; in addition it makes a more compact arrangement. The connecting-rod which operates the cut-off cam is held by clamping at its operating end and when this clamp is set to the proper tension to do the work it acts as a safety device, allowing the connecting-rod to slip if excessive strain is placed upon it. The distinguishing feature between single- and double-stroke machines is the rise-and-fall motion which must be used for raising and lowering the punch-block so that the two punches strike alternately on the head of the wire blank. The mechanism that provides for this is the Ingraham rise-and fall motion which was fully described in the previous chapter. This type of mechanism has the advantage of being located at the top of the machine where it is most accessible and convenient to adjust.

On this machine lubrication is provided for by dripping oil from a cast-iron pot that is mounted on a stud at the head of the machine. From this pot the oil drips to a hole in the bed over the wire line from which it drops on the wire just before the latter enters the dies. Lubrication is an important feature on cold-headers especially when annealed steel or iron wire is being worked, because the lime film which remains from the annealing operation renders the wire hard to eject unless lubricated. The feed is operated by the three-pawl system so that the finest adjustments of feeding lengths may be obtained. The crankshaft bearings are cored out and provided with chain oilers, which are a new feature on cold headers. The capacity of this machine is the heading of blanks 3/16 inch diameter up to 1¼ inch length under the head.

Waterbury-Farrel Double-stroke Solid-die Header

One of the most popular of the double-stroke solid-die headers is that made by the Waterbury Farrel Foundry & Machine Co., Waterbury, Conn. The machine is made in one- and two-cycle types, shown in Figs. 18 and 21, respectively Both of these machines are of the toggle-operated type; the operating principles of one- and two-cycle headers were explained in Chapter I, "Principles of Cold-heading" The machine illustrated in Fig. 18 is the No 0 size and has a capacity for heading

Fig 18. Double-stroke Solid die Cold header One cycle Type—Waterbury Farrel Foundry Make

wire up to and including one-eighth inch in diameter. It is designed to handle wire rivets or blanks up to one inch in length, under the head, this being the largest amount of one-eighth inch wire that can be easily ejected from a solid die. This machine has been highly developed and embodies all the latest improvements in heading machinery. On account of its being of the one-cycle type, striking two blows to each revolution of the flywheel, the machine can be run at a comparatively slow speed and still obtain a large production As is usual in solid-die machines, the wire is fed through feed rolls and and brings up against a rigid feed-stop so that the len arbitrarily

determined. The cut-off bar is of the usual type carrying a cut-off blade at its end and in most instances the cutting off and carrying is done with the aid of a "fiddle-bow" carrier.

This fiddle-bow carrier, perhaps, needs a word of explanation, and for that reason is shown in detail in Fig. 19. The purpose of this type of carrier is to back up the cut-off blade when severing the wire and assist in transporting the blank to the heading die. In Fig. 18 a view of the fiddle-bow carrier may be seen. From this, in connection with Fig. 19, which is a view of the die end of the machine from the inside, it will be seen that the mechanism consists of a carrier *A*, supported in a bracket *B* at one end, pivoted and actuated by end bracket *C* which is bolted to the end of the cut-off slide. At the operating end of carrier *A*, an arm *D* is pivoted, being normally kept in its uppermost position through a

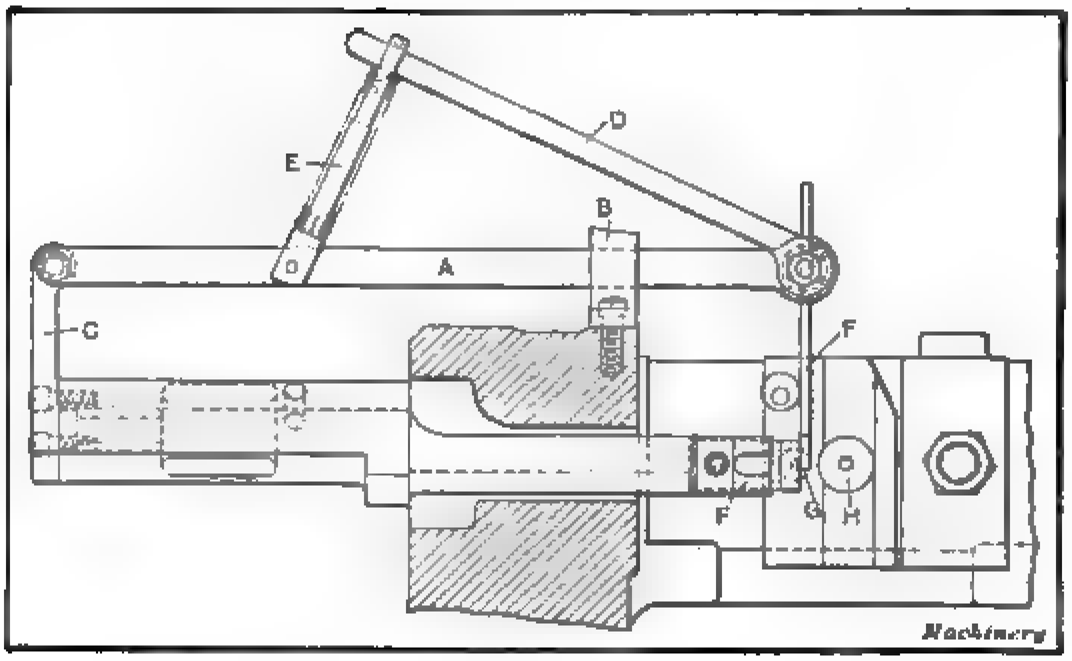


Fig. 19. Construction of the "Fiddle-Bow" Carrier

spring-encircling rod *E*. This rod is slotted at the upper section so that the arm *D* is free to move up or down. Finger *F* is the active part of this carrier, and when the wire emerges from the cut-off quill *G*, this finger is on the opposite side from the cut-off blade, being held there by pressure of the spring located on rod *E*. When the cut-off blade advances, the wire is prevented from being deflected at its outer end under the cutting pressure and is held perfectly square while the cut is being made. Now when the cut-off blade advances with the blank toward the heading die *H*, the fiddle-bow carrier mechanism also advances through contact of bracket *C* with carrier *A* which slides through supporting bracket *B*. After it is in the heading position and the blank partly has entered into the die, the cut-off slide returns and finger *F* of the carrying mechanism snaps back over the wire and brings up against the new length of wire which has advanced through the cut-off quill *G*. The advantage in using this type of carrier is that the wire is supported behind the cutting action and a square end of the blank is the result. This is important, for if the cut is not square, the head of the finished product will be "lop-sided."

The heading operations are actuated by the well-known powerful knuckle-joint mechanism, of which the Waterbury Farrel Foundry Co. are exponents, and as was explained in the preceding chapter, the one-cycle type is characterized by the striking of one long stroke and one short stroke of the heading slide as contrasted with two strokes of even length in the two-cycle type. The relative length of the two strokes may be governed by the design of the toggle mechanism, and it is customary to strike the long blow which does the coning or bulbing first. The second blow, which completes the heading, is taken care of by the short stroke; the reason for this is that concentrating the same amount of power into a short stroke gives a more powerful heading effect—just what is wanted for the final setting of the wire. On this make of ma-

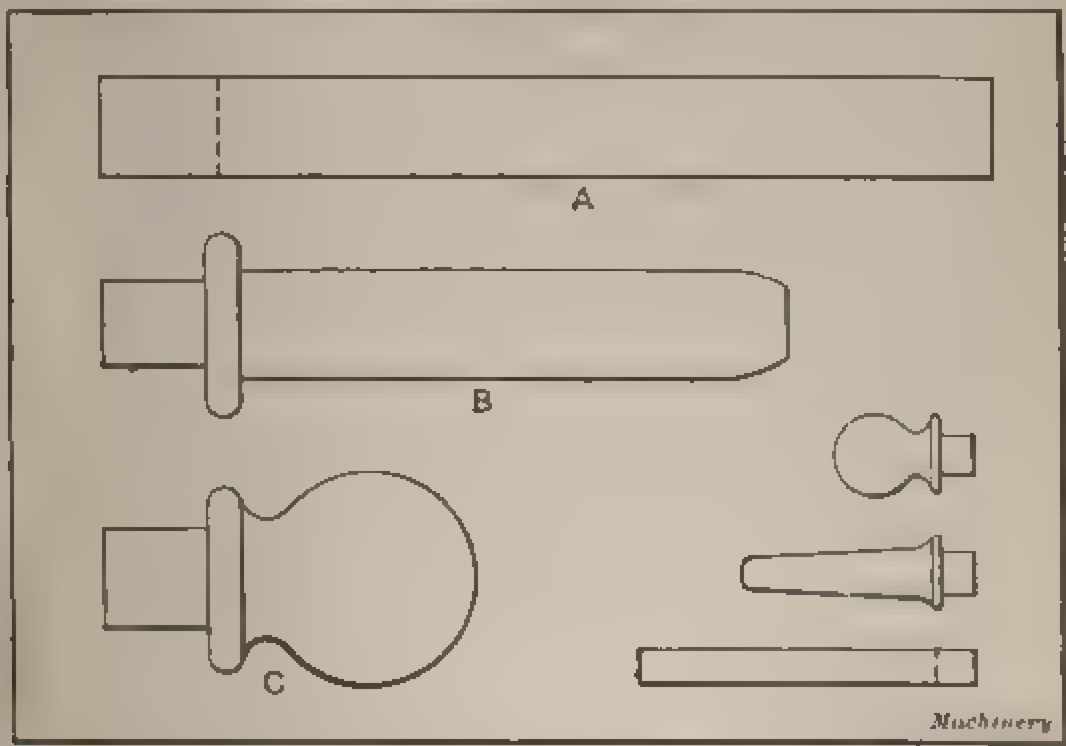


Fig. 20. Typical Examples of Reheading requiring an Open-die Machine

chine, the heading slide has ample wearing surfaces and is gibbed for taking up wear.

The toggles, upon which so much depend in this class of machinery, are made of a special grade of bronze with adjustable steel side plates for taking up wear. The connecting toggle-pin is, of course, of tool steel, hardened and ground. One important feature of the toggle construction is that the machine can easily be brought "off centers" by hand, in case it should get stuck while operating upon a damaged blank or on account of excessive pressure. This construction also makes the setting of the tools easy when operating the machine by hand. The feed mechanism is of the usual type with two grooved cast-iron feed-rolls through which the wire passes. Cast-iron rolls are used as it has been found that the wire slips less than when steel rolls are employed. By means of a pawl arm operated from an eccentric on the crankshaft, the length of the feed can easily be a[illegible]ed even though the machine is in motion. The cut-off is operat[illegible] slide which may be seen at the right of the mac[illegible]rates back and

forth through the cut-off bracket, thus actuating the cut-off blade. A safety slip device is provided so that if excessive strain is brought against the cut-off blade, the blade will not be broken, but will be stopped in its action by the slipping of the safety mechanism. The punch-shifting mechanism is positive, the punch-slide being shifted both in its up and down position against stop-screws so that they will surely be in line when the respective blows are struck. Adjustment is provided so that the punches may be moved sidewise, up or down, or longitudinally. The longitudinal adjustment is obtained from a broad wedge in back of the toggles at the end of the frame. The knockout is located in the end of the bed and ejects the work from the die by means of a lever that pivots in the feed-roll bracket, operated from a cam on the crankshaft. The entire thrust of the heading blow is taken on a stop-screw which backs up the knockout pin and accurately determines the correct length of rivet made.

Double-stroke Solid-die Geared Header—Two-cycle Type

The Waterbury Farrel Foundry Co. also makes a solid-die double-stroke header of the two-cycle type, and Fig. 21 shows the No. 3 size of this machine. It has a capacity for heading three-eighths inch rivets at the rate of fifty-five per minute. This is a geared machine of great power, and it requires two revolutions of the crankshaft to produce each rivet, in accordance with the two-cycle principle. This means that the feeding, cut-off and ejecting mechanism is geared down so that these functions operate only once while the heading slide is making two strokes. While this machine is more powerful than the one-cycle type, it is, of course, slower in its action, and the crankshaft and toggle mechanism must go through twice as many motions to produce a rivet as was the case in the one-cycle type. As in the previously described machine, the wire passes through the feed-rolls and cut-off quill and brings up against the feed-stop. The cut-off blade is actuated in connection with the fiddle-bow carrier which holds the blank to the cut-off blade and assists in carrying it to the heading position in line with the die. The upper heading punch strikes the first blow, forcing the blank into the die and centralizing the wire preparatory to the second blow which is struck by the lower punch, thus forming the finished head. The heading slide then draws back and the punches are shifted down ready to operate on the next blank.

The crankshaft is of large size and runs in bronze lined bearings on the larger machines. The flywheels, of which there are two on the large size machine, are held to the crankshaft between friction disks which slip and prevent damage to the machine should undue strain be imposed. The toggles on the machines are made of the best grade of cast iron, and provision is made for taking up the wear. The feed and cut-off mechanism are the same as in the type of machine previously described, and a safety shear pin is provided so that should the heading die become loose and project out far enough to prevent the cut-off knife from passing, or should the cut-off knife be obstructed from any

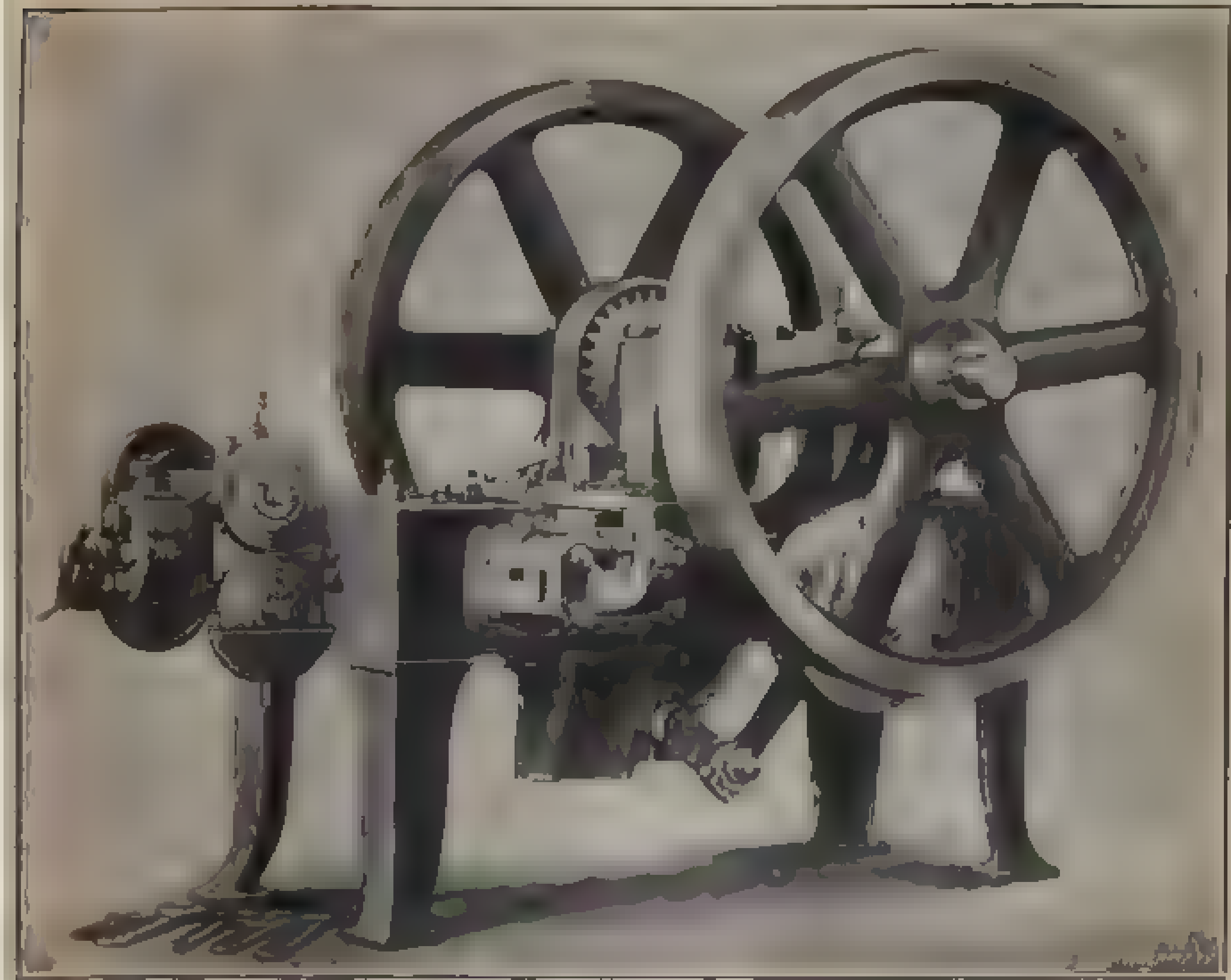


Fig. 21. Double stroke Solid-die Cold-header Two-cycle Type—Waterbury Farrel Foundry Make

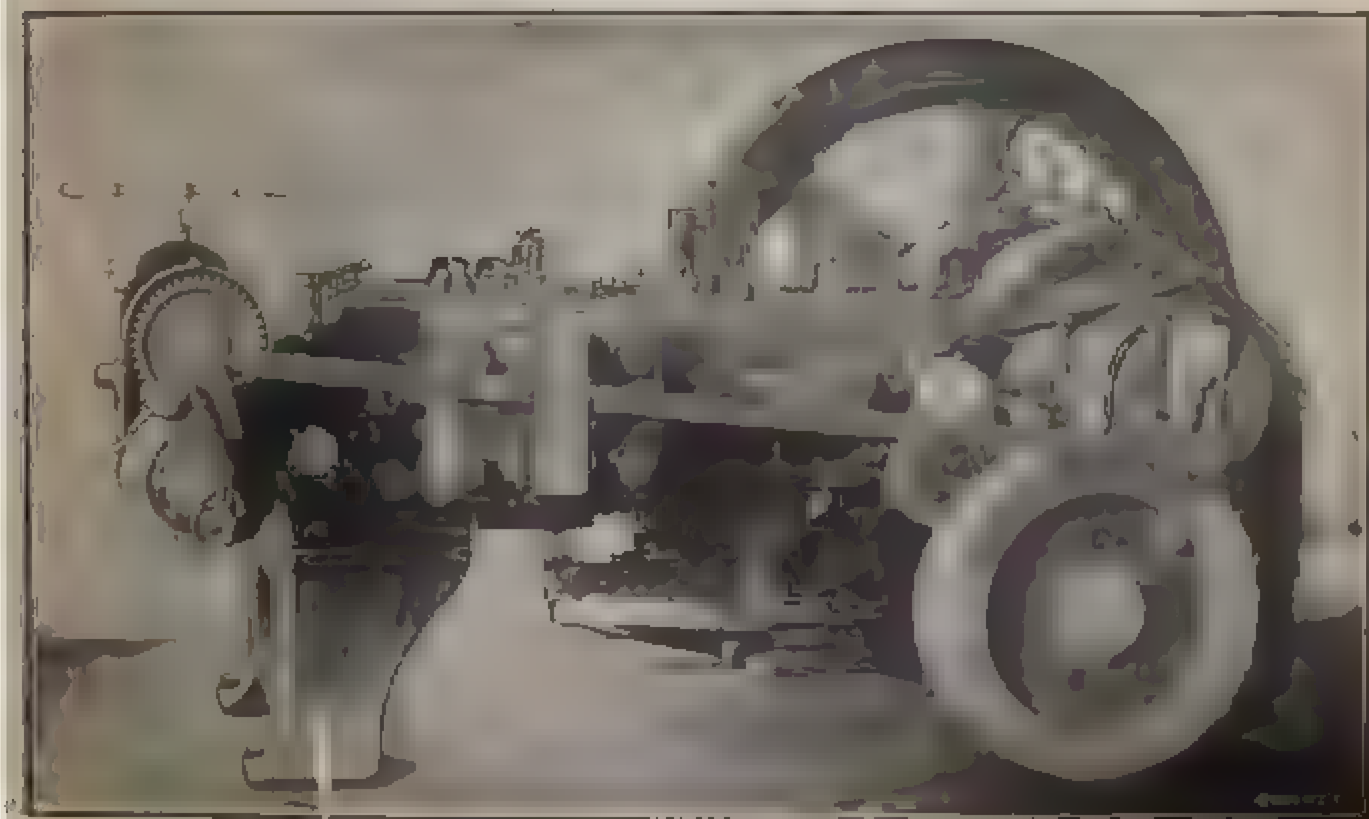


Fig. 5. Double stroke Open die Cold header—E. J. Manville Mak

other cause, the safety shear pin will be severed, causing no other damage to the machine. This shear pin is a plain straight piece so that it is a simple matter to insert a new one.

A relief motion can be furnished for this machine if desired. It consists of a mechanism that allows the knockout pin, against which the blank is forced during the heading operation to draw back after the blow is struck. This allows the metal to flow into the dies more freely on the second blow, and is especially desirable on such work as requires squares or shoulders underneath the head. By a proper knowledge of the use of this relief motion, a great many difficult jobs of heading can be accomplished with facility.

E. J. Manville Double-stroke Open-die Cold-header

Double-stroke cold-headers of the open-die type are the most complicated of the ordinary run of heading machines, for in addition to the rise-and-fall motion for operating the punch block, provision must be made for opening and closing the dies. In Fig. 22 is shown the E. J. Manville double-stroke open-die header. This machine is made in four sizes; the one illustrated is the No. 4 machine which handles wire up to one-half inch diameter. This header is of the crank-operated type, and the wire enters through feed-rolls of the usual type and thence to its cut-off position between the square dies. The dies are then forced sidewise, shearing the wire and carrying the blank over to the heading position. When in line with the backing block, the first or coning punch centers and partly heads the wire, leaving it in condition for the second punch to finish the work. On this machine the punches are locked automatically in both up and down positions while the blows are being struck. Another distinguishing feature of this machine is that the wire feed is operated from the right-hand side of the machine as may be seen in Fig. 22. This leaves the front corner of the machine on the wheel side free from all mechanism so that the operator can observe the working of the tools easily.

The feed-pawl operates only at every second stroke of the machine, for it will be remembered that this is a double-stroke machine. By means of a handwheel which may be seen opposite the lower parts of the ratchet feed wheel a quick and accurate setting of the pawl may be made and it may be regulated while the machine is running. The wire feed is easily started or stopped by a hand lever.

A safety connection is provided between the die-operating cam and the crankshaft, in which there is a cast-iron plate. Should any obstruction prevent the dies from closing, this cast-iron plate will break and drop to the floor, thus instantly disconnecting the crank and cam-slide. An automatic throw-off instantly stops the wire from the feed when this safety device is brought into play. This machine is also provided with a foot brake to assist in stopping the header at the proper point.

Waterbury-Farrel Double-stroke Solid-die Reheader

The varieties of reheaders are almost as numerous as all the other *types* of headers combined. The most common types, however, are the

single- and double-stroke machines of solid- or open-die types. A representative machine of the double-stroke solid-die type is illustrated in Fig. 23 which shows a machine made by the Waterbury Farrel Foundry & Machine Co. This machine takes partly headed rivets or screw blanks after they leave the heading machine proper, and by means of a hopper feed, the blanks are automatically fed to the die in the reheader, thus making the operation entirely automatic. Automatic hopper feeds are of different types, but the usual form consists of a hopper into which the blanks are thrown promiscuously. They are caught by their heads in a blade which has a slot at the top, slightly wider than the body of the blank. This blade rises vertically through the center of the hopper, and as it passes through the mass of blanks, some are sure to be caught

Fig. 23. Double-stroke Solid-die Reheader—Waterbury Farrel Foundry Make

by their heads and are carried to the uppermost position, where there is an extension of the slotted inclined chute. The blanks slide down this chute, which may be seen between the hopper and the flywheel, Fig. 23, and a guard which passes over the heads of the blanks prevents any which are not in the proper position from passing. A transfer slide on a line with the dies supports a pair of fingers that pick a blank from the carrier slide and deliver it at the proper time to the heading die where punches do the reheading. The operation of the heading mechanism is practically the same as that of the standard heading machines; in fact some of the types of standard heading machines can be fitted with reheading attachments. To do this it is necessary to take off the cut-off slide and substitute a transfer slide for conveying the blanks to the die. The reheader here shown has a capacity for handling ⅛ inch wire, producing from 50 to 60 rivets per hour

Cold-heading Operations

After describing the different types of cold-heading machines, the next step is to take up the work for which each type is best ad-

By the process of elimination we can dispose of the open-die types of machines with the simple statement that, if the blank to be produced is over nine or ten diameters of the wire in length under the head, it must be made upon an open-die machine. There are, of course, exceptions to this rule, but they are so special that they need not be considered here. In general, open-die machines are faster than solid-die machines of the same size, as the open-die cut-off mechanism is simple and much more rapid in its action. A rivet or screw-blank made on an open-die machine is easily distinguishable by light raised lines under the head and along opposite sides, caused by the metal being crowded into the crevices between the dies when the heading pressure separates them ever so slightly. The tools used in the open-die machines are more costly to make, and each set is good only for one particular length of rivet. In speaking of the wire in units of diameter, all sizes are included under the general rules. Thus, while only 1¼ inch of ⅛-inch wire can be ejected from a solid die, 3¾ inches would be the limit when working ⅜-inch wire. Similarly, when heading in the single-stroke machines, two and one-half diameters of any size of wire is all that can be put into a head.

Single-stroke Heading

Excluding reheading, we have only the single- and double-stroke heading to consider, since the heading operation on solid- and open-die machines are the same. It has been stated that the limit which may be reached with a single-stroke cold-header is the upsetting of two and one-half diameters of the wire into the head. By this we mean that no matter how soft the wire is, nor how carefully it is cut off, an unsupported length of two and one-half diameters irrespective of the size is all that can be controlled by a single heading punch. If a larger amount of wire is left unsupported and struck by the heading punch it will buckle at the center and be forced over to one side. A typical single-stroke solid-die heading job may be seen at *A*, Fig. 24. The upper illustration shows the wire blank and the lower view the finished piece. At *B*, to the right, is a similar single-stroke heading job, but one which requires an open die machine on account of its length. Now, turning to Fig. 26, the action of the metal under the heading operation may be followed. In the upper illustration the blank is represented with the metal for the head, comprising two diameters, extending from the die. The four illustrations which follow are intended to convey an idea of the way the metal spreads under the advance of the heading punch. The heading punch is, of course, in this case recessed to shape the fillister head to be given the blank. It will be seen that we have here the same result as was obtained in our preliminary experiment with the hammer in the first chapter. The metal, when first under pressure, commences to bulge next to the die and continues spreading out until confined by the limits of the recess in the punch. At the right-hand side of Fig. 26 we have a similar single-stroke heading operation taking place on a wire blank which was too long to be headed in *a solid die*. In this instance the head was oval, countersunk in shape

and two and one-half diameters were upset in the head. This represents practically the limit of a single-stroke heading operation The flow of the metal is represented by the four illustrations within the brace, and the lower view shows the completed blank in the die ready for ejection.

Double-stroke Heading

It is on double-stroke heading operations that we find the most interesting as well as the most difficult work. Referring to Fig. 24, a

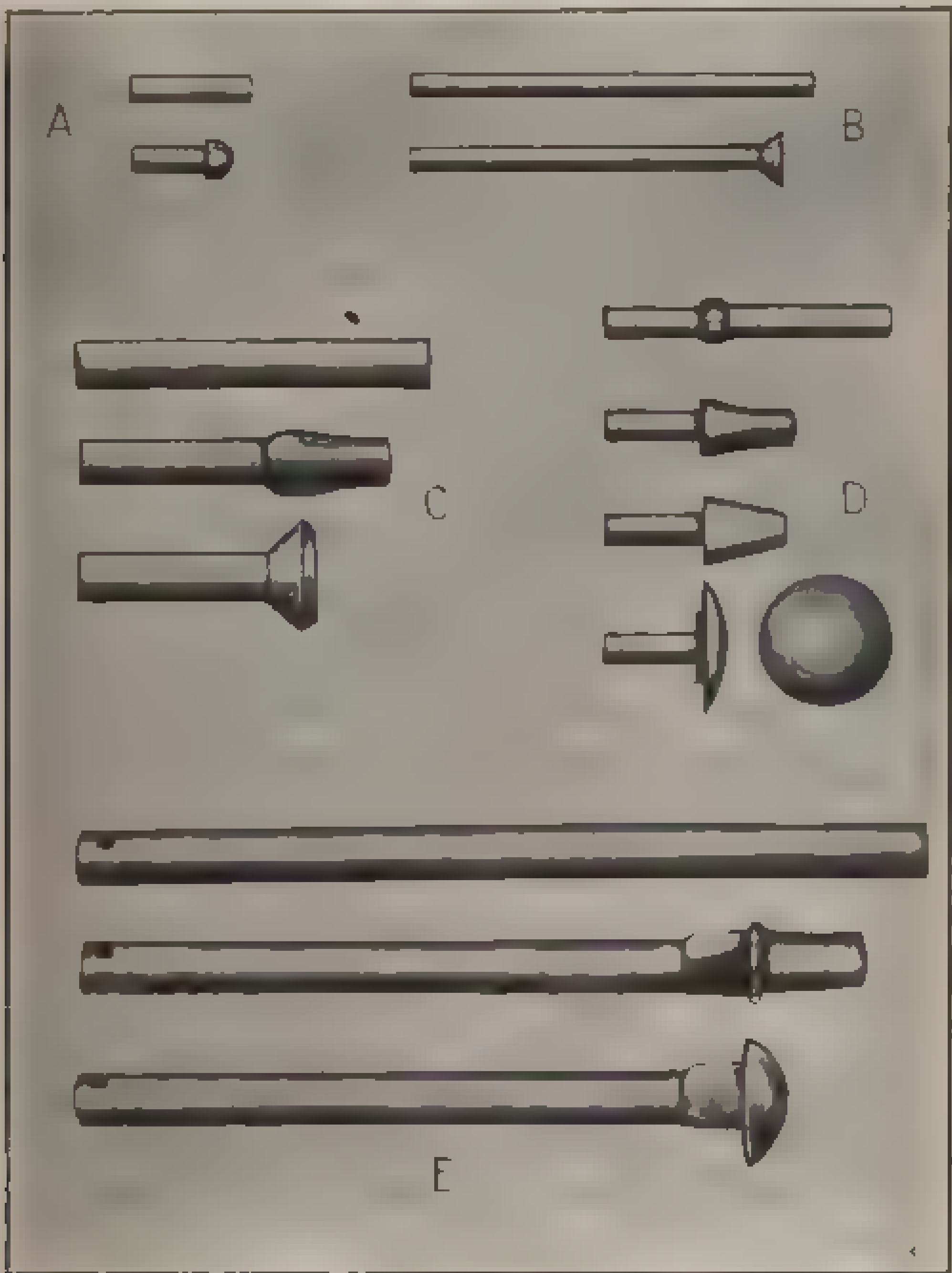


Fig 24 Examples of Cold heading from Different Types of Machines

double-stroke solid-die product may be seen at *C*, and at *E* a double-stroke open-die product. The only reason for using the open-die machine for producing the work shown at *E* is on account of its length. The head in itself could just as well have been produced on a solid-die machine of the double-stroke type

In all double-stroke heading operations the first blow, known as the coning blow, is used for centering and starting the heading --

tion, and leaves the wire in condition to be readily finished by the second blow which does most of the work. Referring again to *C* in Fig. 24, the upper view shows the wire cut off, and in the center is shown the result of the coning blow. The punch which does the coning is shaped so as to "gather" the stock, tapering it at the end and allowing it to partially head next to the die, so that when the second blow

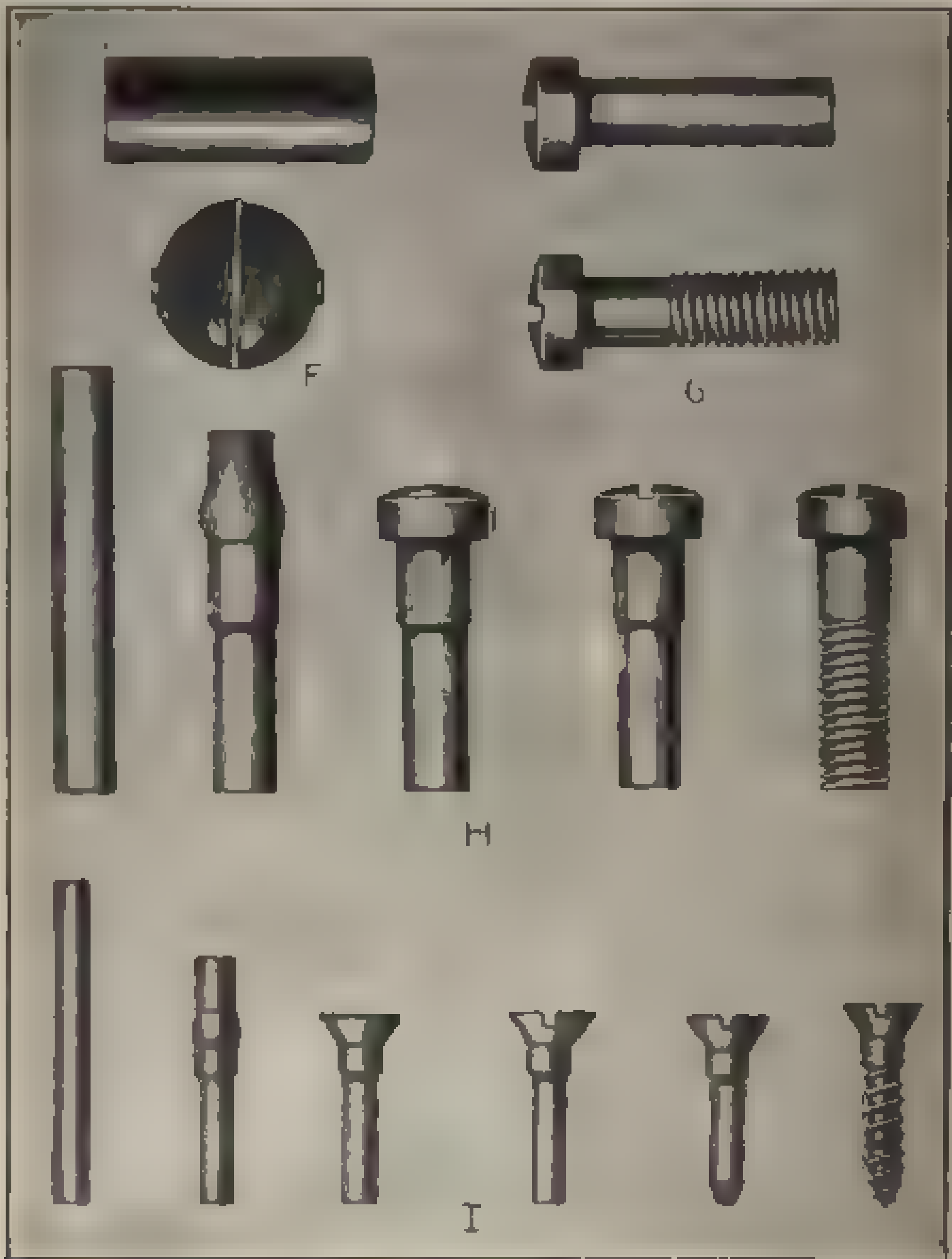


Fig. 25. Some Applications of Cold-heading

is struck the metal will flow naturally toward the desired shape. When the blank is cut off the end is apt to be "out of square" which, of course, means that more metal would be on one side of the head than on the other, and if struck without being centered, the result would be a "lop-sided" head. The limit of the double-stroke heading machine is the upsetting of five diameters of the wire. On certain grades of metal and by using extreme care this rule may be slightly exceeded, but a five-diameter head is very nearly the limit possible. In Fig. 27, at the upper left-hand corner, may be seen the wire blank

which has been cut off and is in the die ready for heading. In this instance there are three and one-half diameters of the wire left projecting from the die to be upset into the head. Directly below this may be seen a view which shows the result of the first or coning punch. The four views which follow show exactly how the wire upsets in forming the head, until at the extreme bottom is shown the completed blank, ready for ejection. On the right-hand side is shown the same series of views to illustrate the making of the head of a wagon bolt, which, because of its length, was made on an open-die double-stroke machine.

Many heading jobs are performed upon a double-stroke machine that would seem to come within the range of the single-stroke machines.

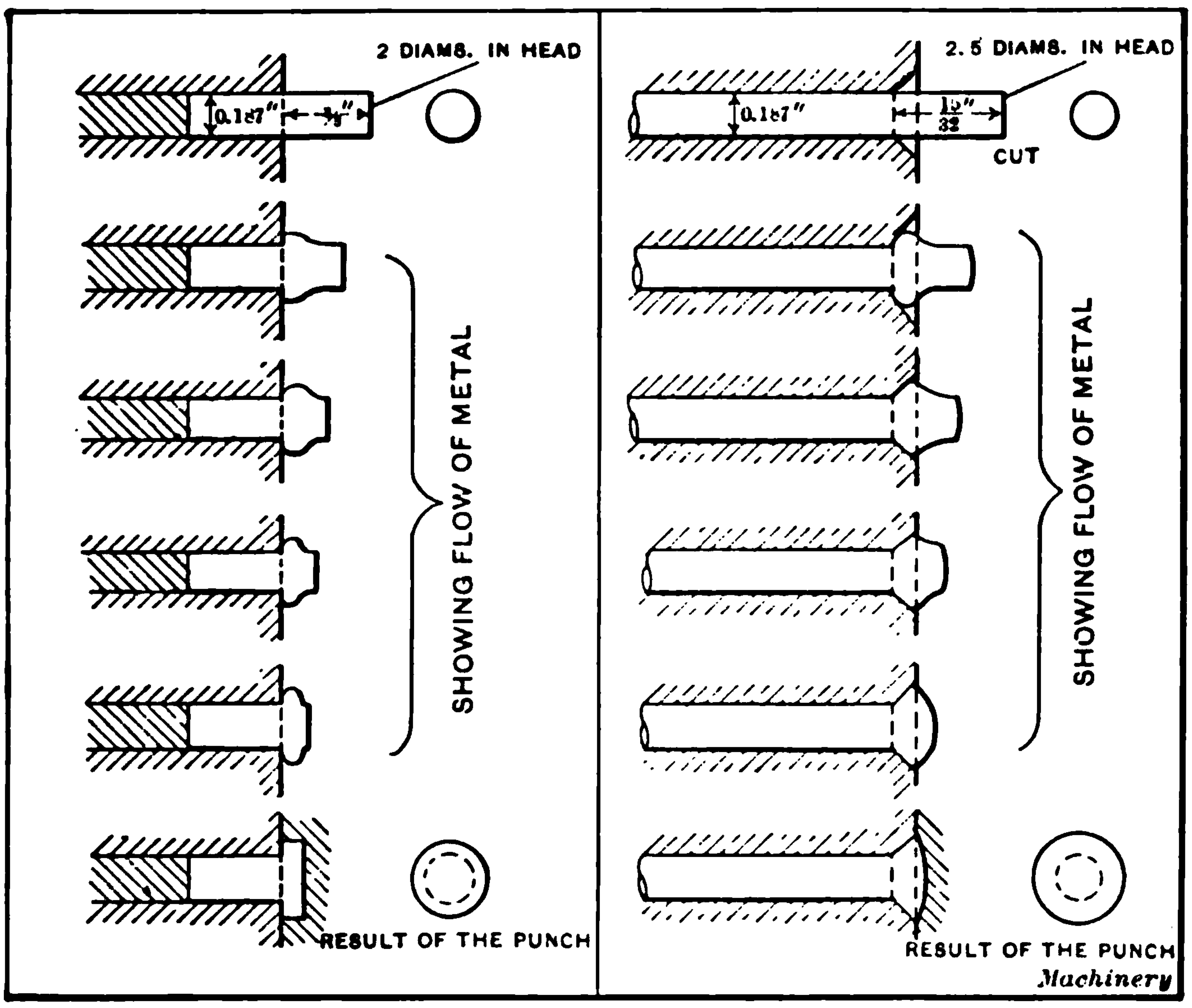


Fig. 26. Evolution of Screw Blanks made on Single-stroke Cold-headers

The reason for this is that with the double-stroke machine the metal can be controlled to a higher degree of accuracy, and for that reason on accurate work the double-stroke machine is often used even though the head requires less than two and one-half diameters of the wire.

Fig. 25 is shown to illustrate some practical applications of cold-heading. At *F* is shown a blank and a headed ball, such as is used in the ball bearing industry. Heading machine manufacturers have given special attention to the heading of steel balls, so that cold-heading is now the usual way of producing ball blanks. At *G* is shown a screw blank and a rolled thread screw, which illustrate a condition of thread rolling practice. When the screw threads are to be rolled, and it is still desirable to have the unthreaded [illegible] the same diameter as the threaded section, [illegible] shown at *H* must be followed. In this sect

steps in making a rolled thread screw of uniform size are shown. First we have the cut off blank; second, the partly headed blank in which the section which is to be left unthreaded has been upset enough larger to match up with the diameter of the thread which will be rolled upon the lower section. The completely headed blank is shown next, then the slotted head, and last, the finished screw with the rolled thread. Similarly at *I* are shown the successive steps in making a wood screw, and the manufacture of machine and wood screws like those shown forms one of the most extensive uses for cold-heading machinery.

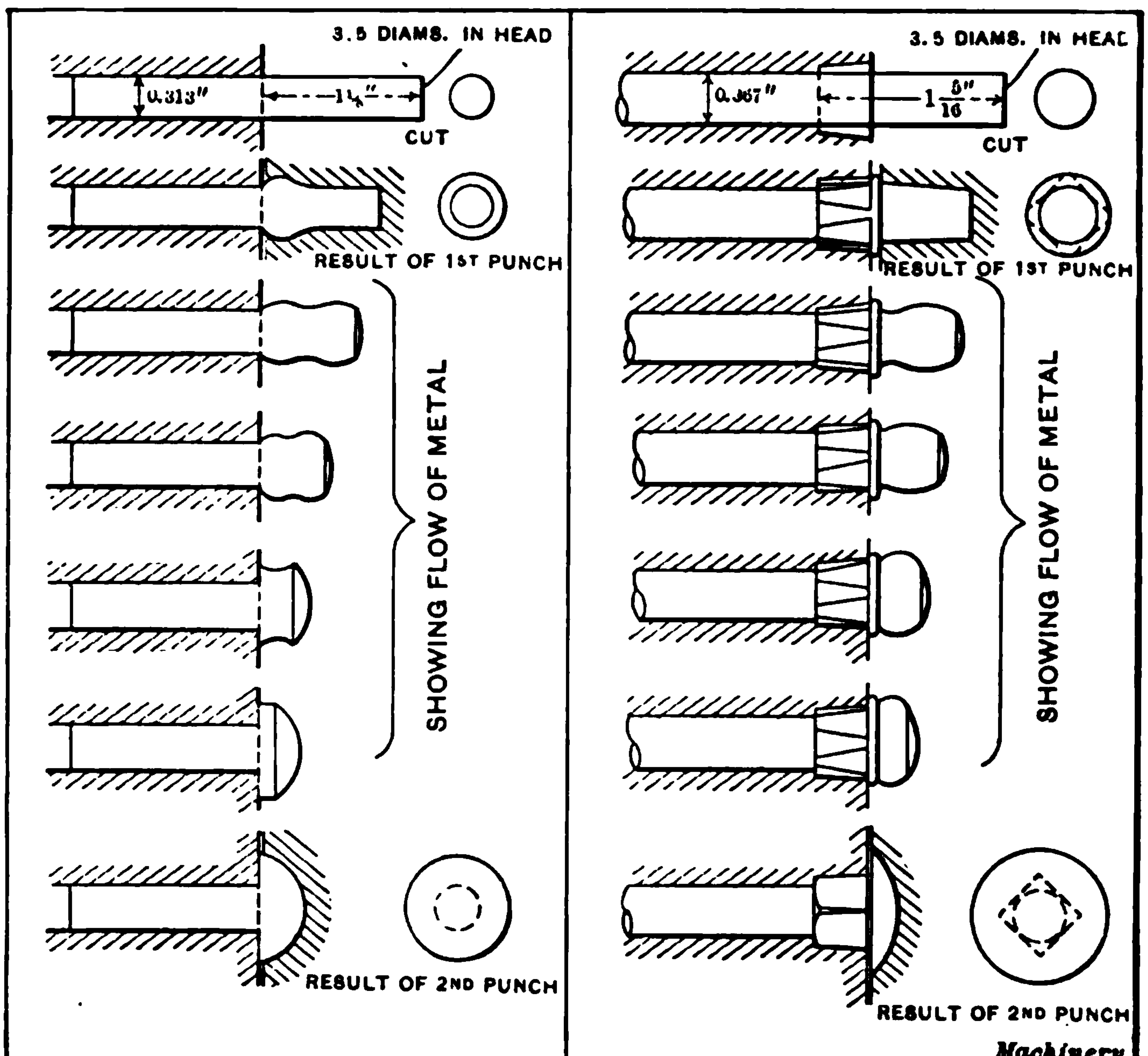


Fig. 27. Evolution of Screw Blanks made on Double-stroke Cold-headers

Reheading

Reheading is a more important branch of cold-heading than is generally recognized, and some of the "stunts" which may be accomplished with the proper knowledge of reheading machinery strongly emphasize this fact. Reheading is usually necessary for one of two reasons; either to produce a head which would require too much work for the double-stroke machine to do, or to produce a head which is larger at the end than at the shoulders as in the case of hinge pins like those shown in Fig. 20. Even though the blanks are usually annealed before going to the reheaders, this operation is one which requires a great deal of force because the metal has already been compressed and is very dense before being reheaded.

A good example of reheading work is shown at *D* in Fig. 24. The first two pieces represent the work of the double-stroke solid-die head-

ing machine, and from this point, the blanks are handled in a double-stroke solid-die reheader. The third illustration from the top in this group shows the result of the first reheading operation, and a plan and side elevation of the completed piece is shown beneath. The diameter of the head is very great, as compared with the diameter of the shank of the rivet and it will be readily appreciated that four operations were necessary to keep the metal under control and completely head the piece.

For producing hinge pins like that shown in Fig. 20, an open-die reheader is necessary. This is really a very interesting job of cold-heading, as there are eight diameters of the wire in this head. Two operations are necessary to bring the blank *A* into the position shown at *B* and these operations are performed upon a double-stroke header. After this point, the partly formed blanks are annealed and finished in a double-stroke open-die reheader, producing the result shown at *C* in two additional operations. The hinge pin shown at the right-hand side is similar but smaller.

CHAPTER III

COLD-HEADING DIES AND TOOLS

In the first two chapters the principles and different types of cold-heading machines are treated, together with the character of work for which each machine was adapted. In this chapter we will consider in detail the tools for solid- and open-die machines, including an outline of the operations connected with their making. As there are numerous little kinks and methods followed by individual heading die makers, it will only be possible to strike an average and outline the general processes of making the tool. As in other lines of tool-

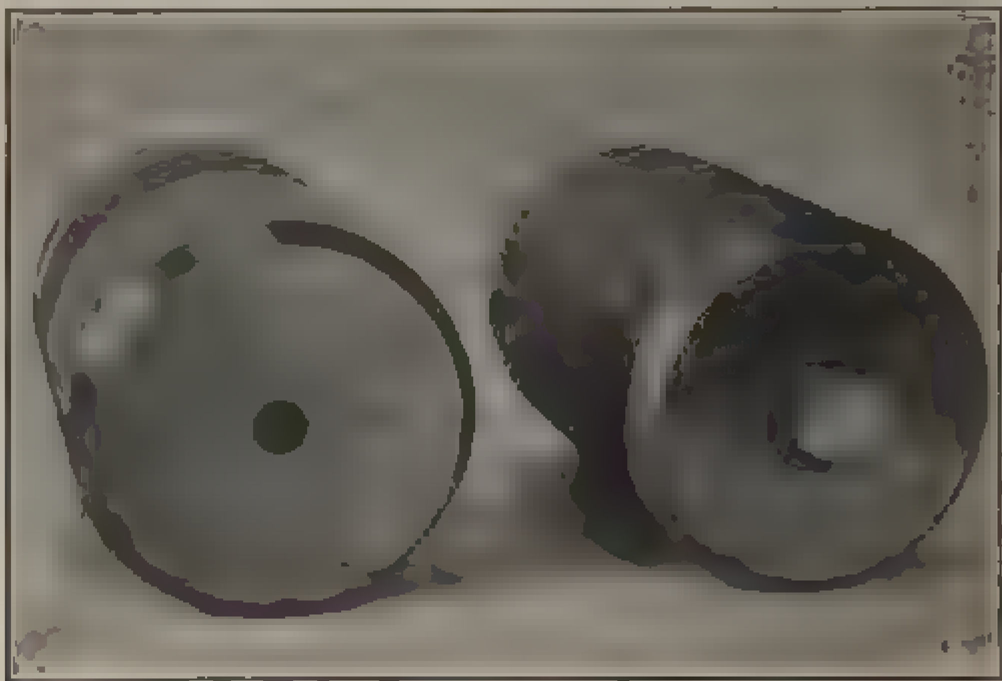


Fig. 28. A Pair of Solid Dies for the Cold-header

making, no two workmen's ideas on a given set of tools will agree, although each may be right from his own point of view.

Tools for cold-heading machines may be roughly divided into two classes—those used in solid-die machines and those used in open-die machines. Whether the tools are for a single- or double-blow machine affects only one extra tool, namely, the upsetting or coning punch. In all other respects the tools are similar. The chief difference between the tools for the solid-die and open-die machines lies in the dies themselves, the punches being the same in both cases. Figs. 28 and 29 illustrate the difference between dies for the solid- and open-die machines. Fig. 28 shows a die and punch for a solid-die machine. These tools are very simple, being merely sections of round stock, the die being made with a hole to agree with the diameter of the wire, and the punch with a cavity of the correct shape for forming the head. In Fig. 29 a pair of open dies, without the punch, is illustrated. In this case the wire is held between the halves of the die, and the cutting

off is done by the dies themselves, as was explained in Chapter I. Therefore a pair of dies for the open-die machine must be of exactly the same length as the finished rivet under the head. The dies shown in Fig. 29 were made for forming a carriage bolt having a square shoulder under the head. By referring to Fig. 30, a set of tools for a solid-die machine may be seen in place. These consist, in the case of a single-blow machine, of the die *A*, in which the wire blank *B* is held for heading; the punch *C* which shapes the head and is actuated by the ram of the machine, the cut-off die or quill *D*, which is similar to the heading die, having a hole through its length through which the wire is fed against a feed-stop (not shown) the proper distance, and is then cut off by the cut-off blade *E*. The face of the cut-off die is crowned to help the cut-off blade do its work. Mounted on the cut-off blade is a carrier *F* that holds the blank to the cut-off blade so that it may be carried over to the heading die. A

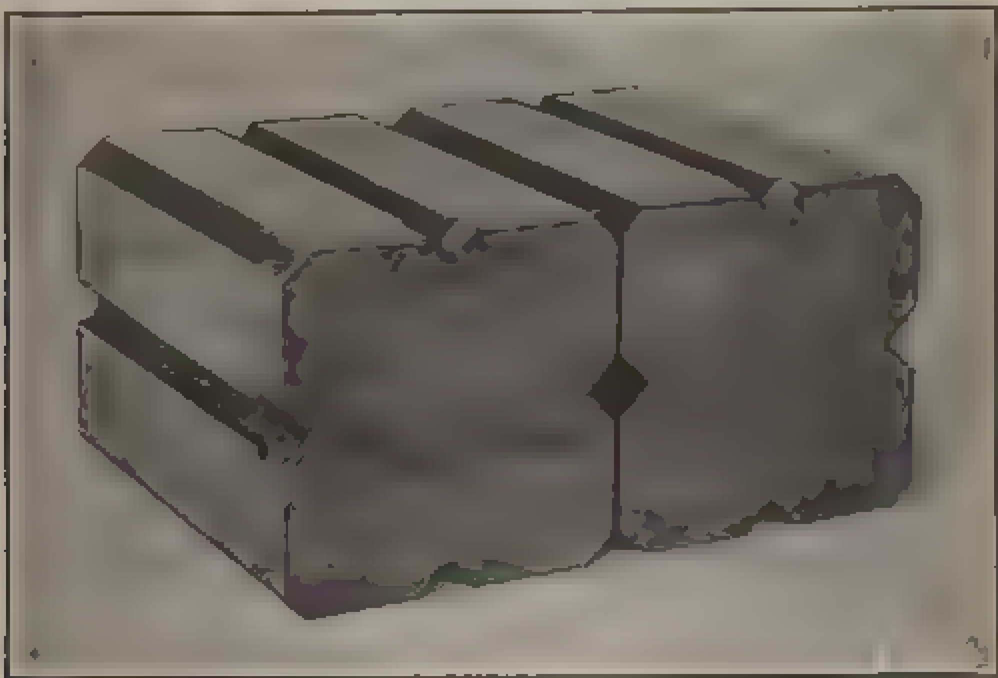


Fig. 29. A Pair of Open Dies for the Cold-header

backing pin *G* fits in the hole in the heading die and regulates the length of the rivet under the head; it also serves as an ejector after the rivet has been finished. In Fig. 33 may be seen a set of heading tools, with the exception of the cut-off quill. These particular tools were used in making a round-head screw that required two blows to form the head. The die is shown at *A*; the second-operation punch at *B*; the first-operation punch at *C*; the backing pin at *D*; and the cut-off blade without the carrier at *E*. At *F* may be seen the cut-off blank; at *G* the coned blank resulting from the first operation; and at *H* the finished round-head screw. If this same work were to be done in an open-die machine, the cut-off blade and the backing pin and die would be eliminated and a pair of open dies substituted.

Making a Solid Die

At first glance, the solid die appears to be simply a round piece of stock with a hole extending through it to receive the wire. There are, nevertheless, many points to be considered in making this die, and

without the knowledge of them the tools would never work satisfactorily. The heading dies, punches and cutting-off tools are made from a good grade of tool steel, annealed stock being preferred. The tools are sometimes made of low carbon steel and then carbonized, and at least one large user of heading machines follows this method exclusively, but unless the best of carbonizing and hardening facilities are available it would be inadvisable.

The length and diameter of a heading die are governed by the size of the machine in which the die is to be used. An idea of the proportion of the diameter to the length may be obtained by stating that

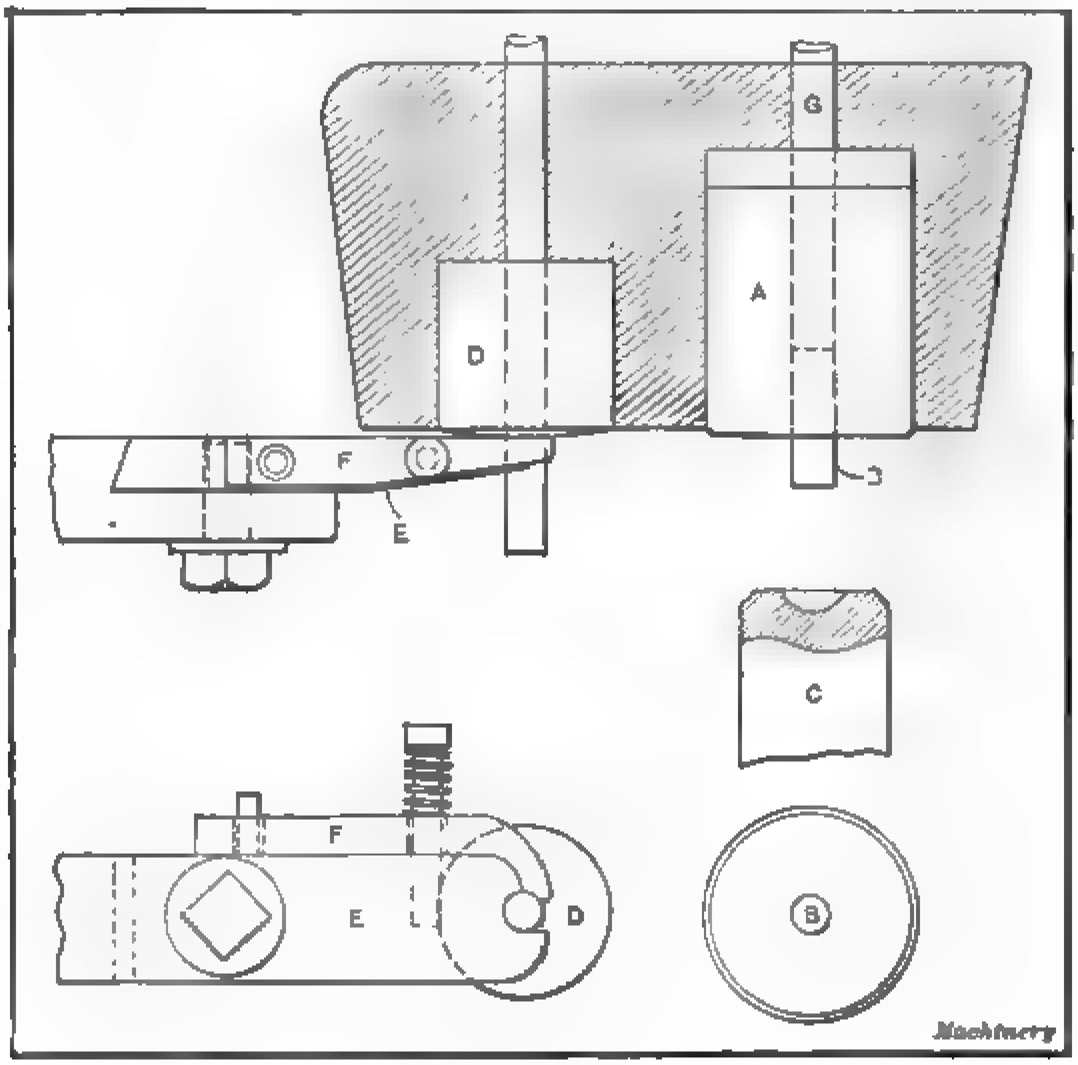


Fig. 30. Section of Cold-header showing Locations of Principal Tools

for handling wire up to 1/8 inch diameter, a die of 7/8 inch diameter l
1 5/8 inch long agrees with good practice, and for handling 1/2 inch wi
the die may be 3 3/8 inches in diameter by 4 1/2 inches in length. Th
dimensions are not arbitrary, but are, of course, determined by
make and size of the machine in which they are to be used. In F
35 is illustrated a little kink by means of which considerable die-s
may be saved. In this case a backing block is made to replace a
one-third the length of the die. The dies themselves may thu
made correspondingly short, and as this pillar block is used be
each die, one-third of the steel of each heading die is saved.

Fig. 31 shows, in section, a typical heading die of the solid

just made and ready for hardening. This die is given with actual dimensions so that the shrinkage allowances may be duly noted The length of the die is 1⅜ inch and the diameter ⅞ inch, and it is to be used for heading rivets from 0.105 inch wire First, a hole a few thousandths under 0 105 inch diameter is drilled through the die The die is then relieved from the back for a short distance with a No 33 drill, enlarging this section to 0 113 inch. A tapered reamer which has a taper of about 0 003 inch to the inch is then used to ream out the unrelieved section very nearly to the face of the die At this point the die is hardened and this operation causes the mouth of the die to "open," leaving it about as shown in Fig 32 Using emery and oil, the die is then lapped out from the back until the hole measures

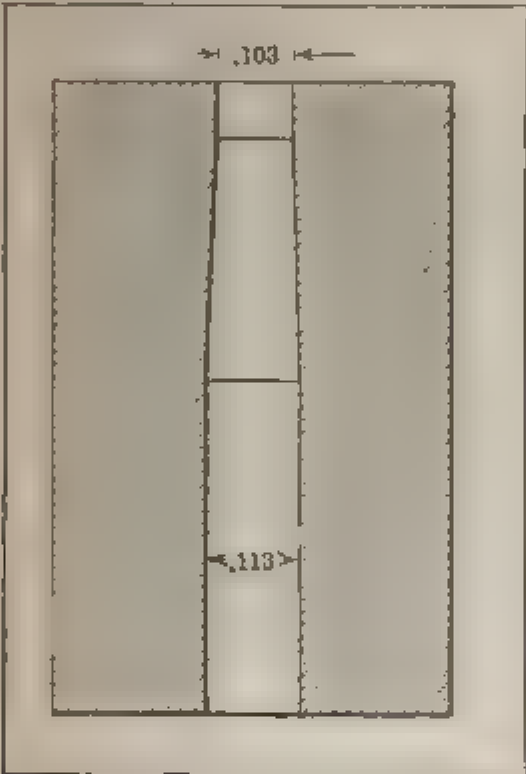


Fig. 31. Section of Solid Die, with Allowances for Hardening

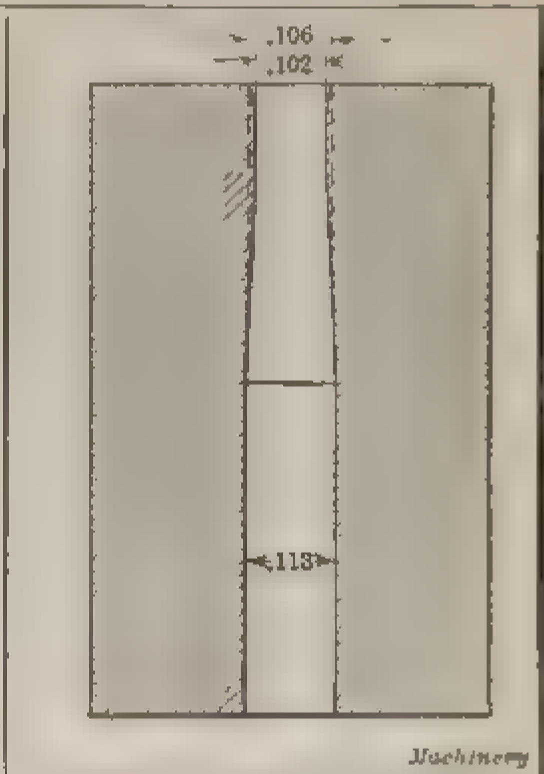


Fig. 32. Section of Solid Die showing Shrinkage in Hardening

0.106 inch diameter, this being 0.001 inch over the diameter of the wire, allowing plenty of play for the working of the stock

The hardening operation is comparatively simple, the requirements being to have the die, especially the section adjacent to the hole, very hard. A useful kink to be followed in securing the desired hardness is illustrated in Fig. 44 This consists of a funnel shaped bushing which is threaded so that it may be screwed onto the ordinary water faucet The die is brought to the right heat and held under this conical bushing and the water turned on full force When the water is turned on, the face of the die and the hole receive a sudden quenching, giving it the extreme hardness that is necessary.

The Punches

Before a punch can be correctly made for any rivet except a "flat-head" a counterbore is necessary to obtain the exact shape of the cavity In the case of flat-head screws or rivets, the punch consists simply of a length of round steel having a perfectly flat face with

chamfered edges. With round or fillistered head blanks, however, the finish punch must contain a cavity of the exact size and shape of the head. In making a punch like that shown in Fig. 33 for a round-head rivet, a reamer of the same semi-spherical shape is necessary. The reamer is turned up in the lathe, leaving a flat shoulder to limit the depth of the cut. The "half type" reamer is employed, and is relieved only for a short distance behind the cutting edge so that a good bearing is secured while the punch is being reamed, resulting in a smoothly finished cavity. In hardening these reamers they are drawn to a straw color. In the case of difficult shaped heads, it is often found advisable to hammer a piece of lead into the soft die so that measurements may be taken and checked up with the sample. Weight forms an important feature in determining the amount of metal which

Fig. 38. A Set of Heading Tools and Work from a Double-blow Cold-header

goes into the head. In setting up the machine, for instance, the toolmaker will often compare the weights of his rivet and the sample in order to see if the right amount of stock is being used. By cutting off the head close to the shoulder and weighing it, he can determine the amount of stock required, and by balancing the head with an equal weight of wire stock, he can readily determine the distance to which to set the wire feed.

In the case of double-blow machines, in which an upsetting or coning punch is used, there seems to be no definite rule that can be laid down for the shaping of the cavity in the coning punch. As before explained, the idea of the coning punch is to upset the metal and leave it in condition for the final distribution into the finished head. Generally speaking, this intermediate shape is that of a truncated cone, the base of which is very nearly the diameter of the finished head, and the length of which is about two-thirds the amount of wire advanced by the wire feed. The top of the wire is left approximately the same diameter as the blank and slightly rounded. If a very large

amount of metal must be put into the head, the angle of the cavity in the coning punch is made as obtuse as possible.

It is customary to relieve the coning punch about as shown at C in Fig. 33, the object being to remove all danger of interference with the cut-off blade, because the coning punch strikes the wire blank just as the cutting-off blade releases it; therefore it helps matters to have the cut-off blade relieved as well as the coning punch. When the coning punch is to be used in connection with a countersunk die for flat-head screws, it is relieved about as shown in Fig. 38. By so doing, the wire in the cone is supported and driven down into the countersunk section of the die, instead of being left out at the line of the die face. There are so many governing factors bearing upon the shapes of coning punches that it must be left largely to the judgment of the

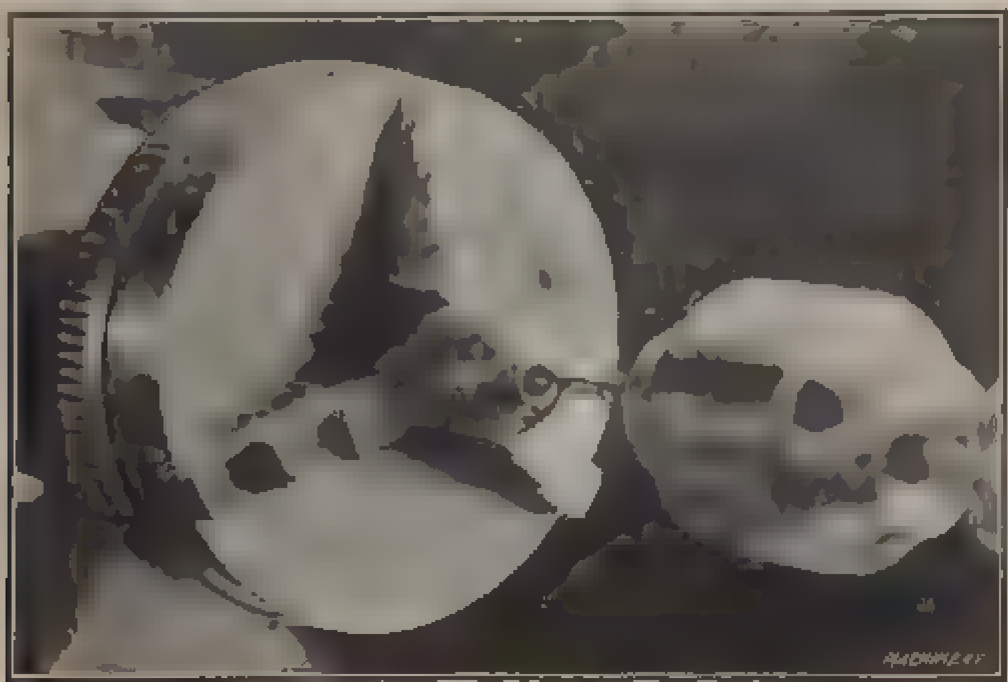


Fig. 34. Reaming out a Coning Punch

toolmaker. Punches for fillister head or other deep types of punches where the blanks would be likely to stick are often fitted with spring ejector pins as shown in Fig. 39. Ordinarily the die is the member in which sticking is most prevalent, but when the blank is short and the head is deep sticking will be encountered in the punch.

In the manufacture of very cheap screws, the slot in the head is often formed by the heading punch instead of being sawed. This means that the cavity in the heading punch must have a ridge of steel left standing to drive the metal down for the slot. To cut the cavity to this shape would be practically impossible; therefore the common practice is to hub the punch. The hub is made by turning up a blank of steel with a face of the same shape as the head of the screw to be produced. A slot is then milled or filed in the center of the head of the hub, after which it is hardened and drawn to a straw temper. Before being hubbed, the face of the heading punch is first convexed so as to leave the highest point at the center, thus providing enough stock to make a well formed cavity. The tendency is for the metal in the punch to sink away from the slot in the hub; therefore by

ving an excess amount of metal at this point, the slot is completely .ed when the punch is hubbed. After being hubbed, the punch is ced off, of course, and the sides turned up for hardening. Fig. 36 ;presents the hub and the punch-blank before hubbing and Fig. 37 hows the hubbed punch before being faced off.

The Cut-off Tools

The cut-off die is simply a section of round stock having a hole extending through it slightly larger in diameter than that of the wire being worked. On small sizes of wire, 0.001 inch provides sufficient clearance. The face of this die is crowned slightly so that the cut-off blade which works in conjunction with it may act without binding on any other part of the die face. The cut-off blade is shown at *E* in Fig. 30, from which it will be seen that the end is filed out U-shaped, so as to partly enclose the wire, thus supporting it while the cutting-off

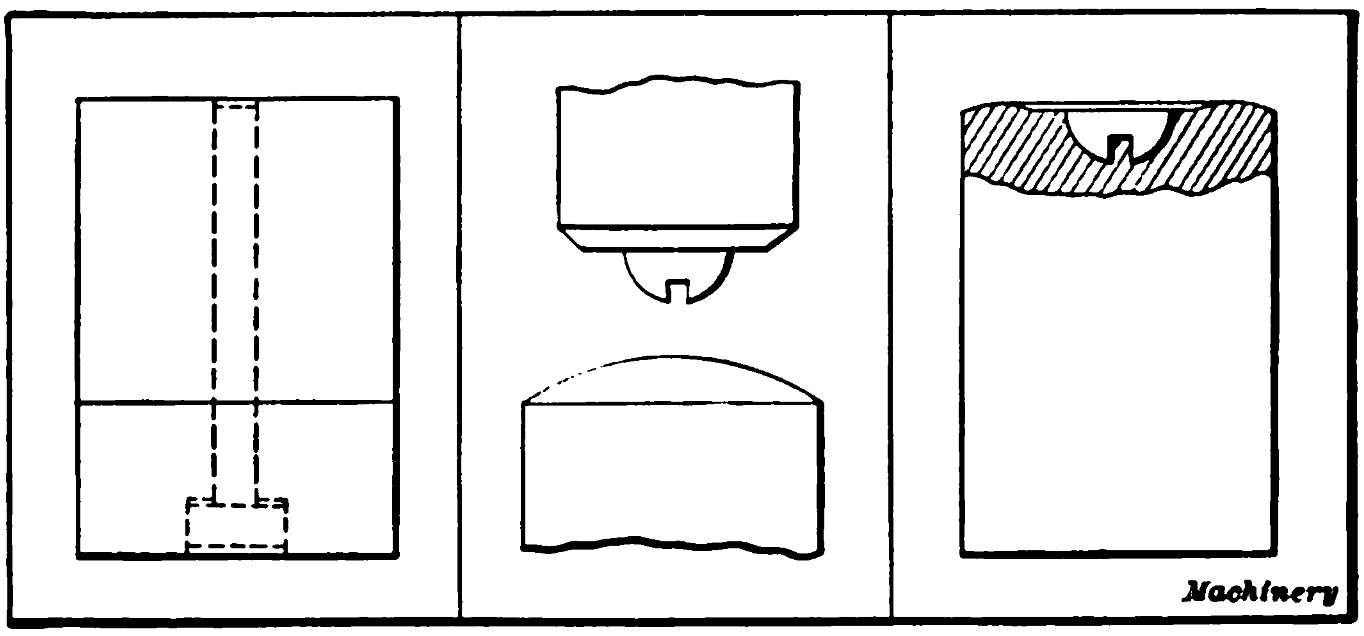


Fig. 35. A Kink for saving Die Stock   Fig. 36. A "Hub" and a Punch Blank   Fig. 37. Punch after hubbing

operation is taking place. A spring-finger *F* is fitted to the cut-off blade that snaps over the wire when the cut-off blade advances for cutting and holds the blank so that it can be carried to the heading die. There are different methods of applying the spring-finger or carrier, but a good way is illustrated in Fig. 30. Here the spring pressure is supplied from the spiral spring over the stud near the center, while the pin at the end operates in an enlarged hole in the finger serving merely as a guide to prevent the finger from swiveling. Both cut-off die and blade are hardened and drawn to a straw temper. There is little to be said about the backing pin which is shown at *D* in Fig. 33 except that as it receives the full force of the heading blow it must be hardened and drawn to a very dark purple.

Tools for Open-die Machines

The only explanation required for tools for the open-die machines the operations connected with the making of the die halves. The which are illustrated in Fig. 29, are made by shaping up square tions of tool steel to fit the die-holding block of the header. halves of the die are left large enough in size to allow for grind ^and down the center of each face is milled a half-round groove

size slightly less than the diameter of the wire which is to be handled in the header. After the bulk of the stock has been milled out in this manner, as shown in Fig. 43, the halves are clamped in a special holder illustrated in Fig. 41 and a reamer of the proper size is run through the hole, taking half the stock from each die face. Set-screws are provided on the die-holding box to clamp the two halves together and take up end play while this operation is being performed. Each of the four pairs of faces is treated in this manner and, of course, they are marked so that they can be mated readily. The object of having all four faces grooved is simply to make use of the other three sides of

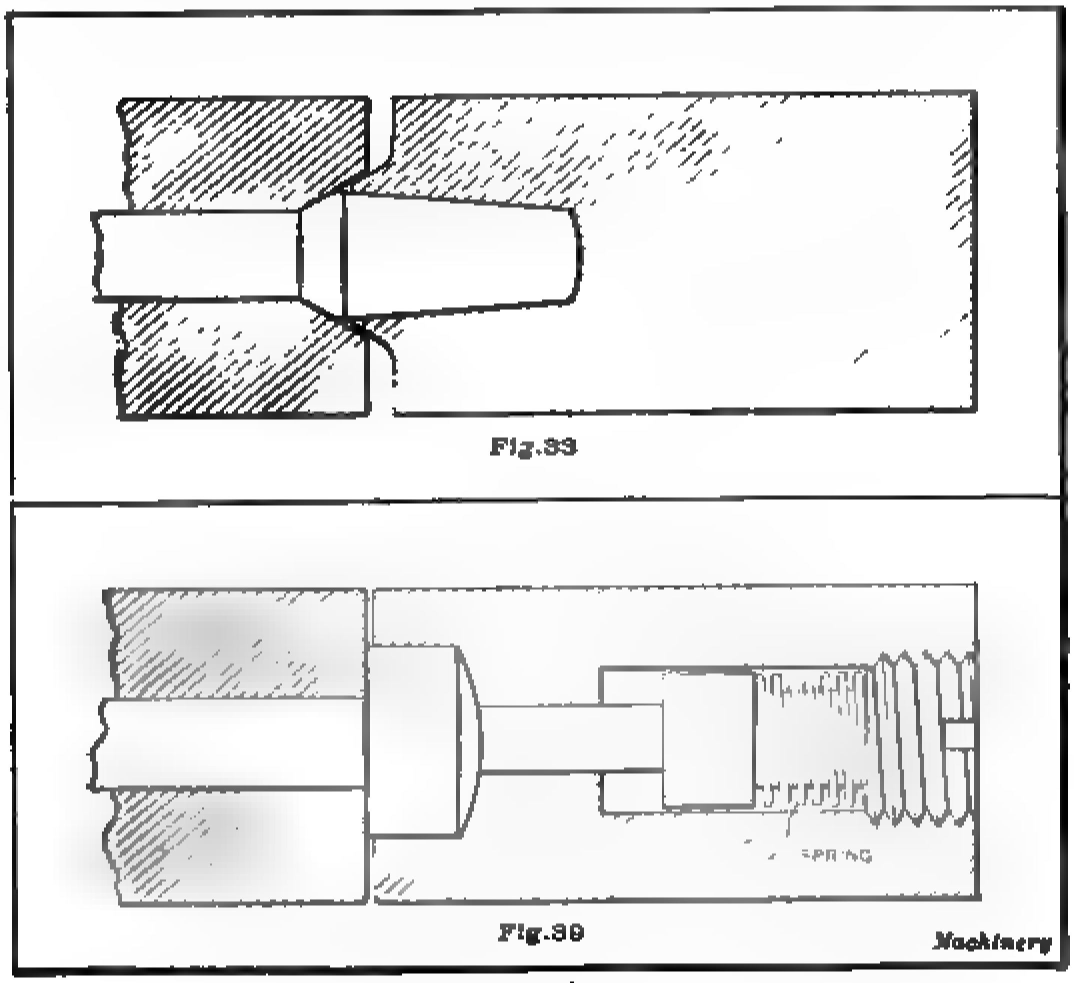


Fig. 38. Coning Punch relieved to force Wire into the Countersunk Head of the Die. Fig. 39. Spring-pin in Punch which facilitates Ejection

the die; thus as soon as one pair of grooves has worn out of round, the dies are simply turned to bring a new pair of faces into use. As was explained in Chapter I, the object of chamfering the corners of the die halves is to facilitate the opening of the dies by the spring-finger on the machine. Fig. 42 shows the manner in which the square section of a die for producing a carriage bolt is machined. This square section comes under the head of the bolt and, therefore, must be provided for in the dies. After reaming out the grooves in the die faces the square outline is marked on each of the faces of the die, and the lines scribed for the depth. A starting point is made by chipping a groove at the proper distance from the face of the die, and the rest of the stock is removed by a square shaper tool, thinned down at the face to permit of its starting in the chiseled groove. Each of

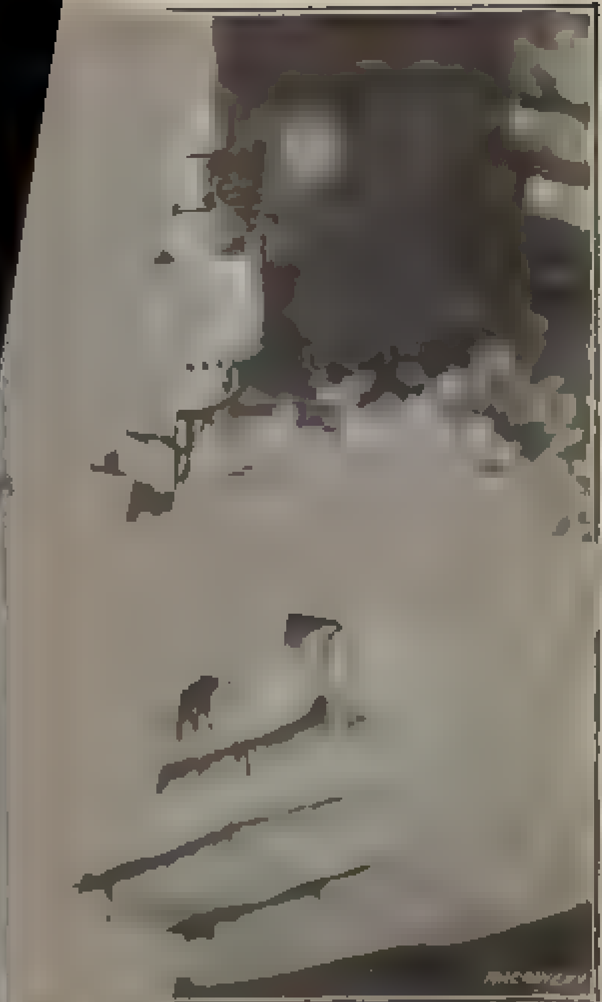


Fig. 40. Drilling out a Solid Die

Fig. 41 Reaming a Pair of Open Dies

Fig. 42 Shaping Square Section in an Open Die

faces of the two die halves is similarly treated. As with solid dies, the open dies are hardened and the faces and ... are ground before being put into use. It is very important that the faces of the dies be properly ground so that they will come close together and prevent the headed metal from bulging out in the form of fins on the sides of the work

In grinding the sides of the die halves, the stock taken off permits the faces to come together far enough to flatten the circular opening in which the wire is held. This provides the necessary clearance for gripping the wire.

Multiple solid dies are often made for the sake of economizing in steel Examples of such dies are shown in Figs 45 and 46 The die in Fig 45 has three openings so that after one of them has been worn out of round, the die may be moved along in the special holder necessary to hold a square block and another hole put into use If the work is such that the die can be made without clearance, the block

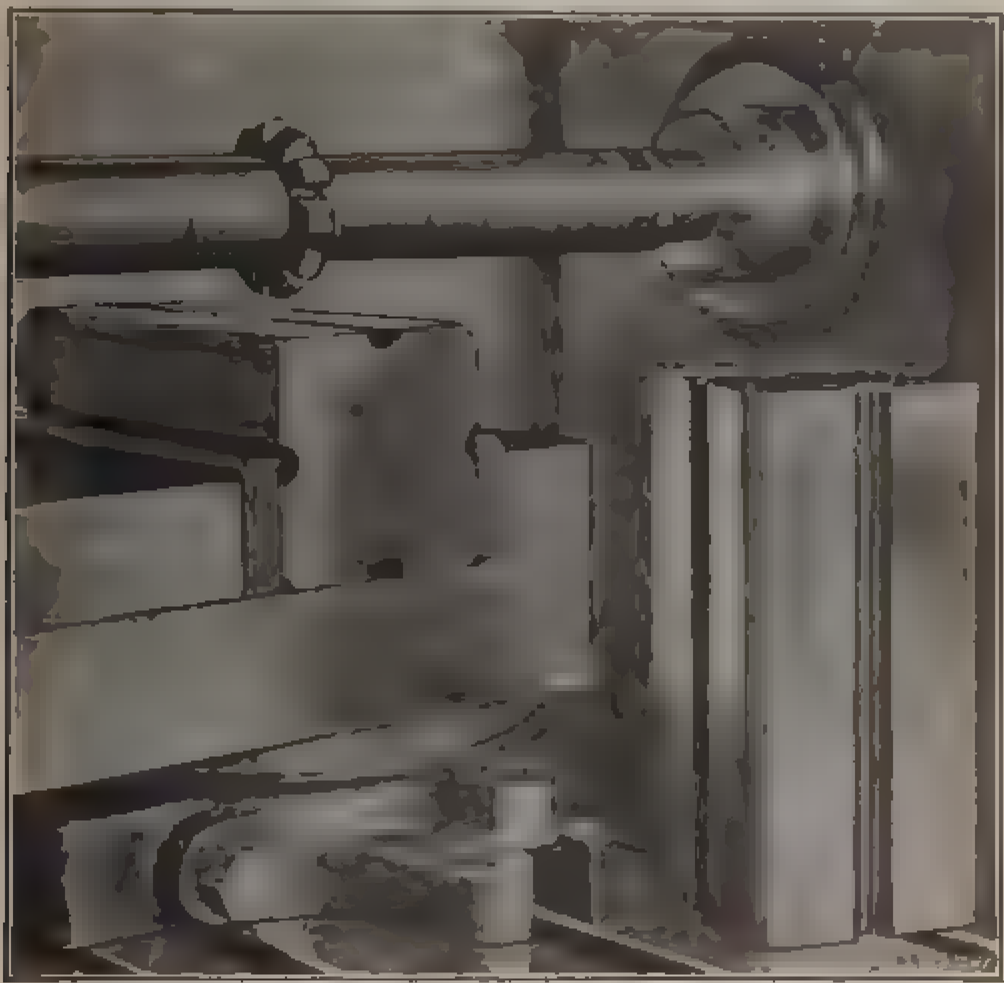


Fig. 43 Milling the Grooves in Open Dies

can then be reversed and the opposite ends of the three holes used. Similarly, in Fig. 46 is a multiple die of hexagonal shape, providing eighteen working openings. As a general rule, however, multiple dies are not used, because of the trouble caused by special die-holders. The plan of reversing the die to use the opposite end of the hole has disadvantages on some work where the heading blows close the hole insomuch that the necessary lapping out makes the method more troublesome than beneficial

Setting-up for a Plain Heading Operation in the Header

In setting-up in a solid-die header, the first step is to put in the cut-off die and adjust the cut-off blade The blade is adjusted by snapping the finger over the wire, and while thus held it is clamped in position against the cut-off die. The die is next bolted into its seat and the

backing pin adjusted to size the length of the rivet under the head. The finish punch, in the case of a double-blow machine, is then located in the punch-holder. The coning punch is next held in the punch holder, and, if necessary, it is adjusted to bring its face into line with the finish punch. The finish punch should be set without backing or "shimming" of any kind, but if necessary the coning punch may be shimmed up to agree with it. The stroke is then adjusted so that the punch faces almost touch the die face. After this, the wire feed may be set and the machine is ready to be operated. On every job there is more or less adjusting of the feed, grip and ram movements to obtain the exact results.

In setting up the tools on an open-die machine there is, of course, no cut-off to be taken into consideration other than the proper setting

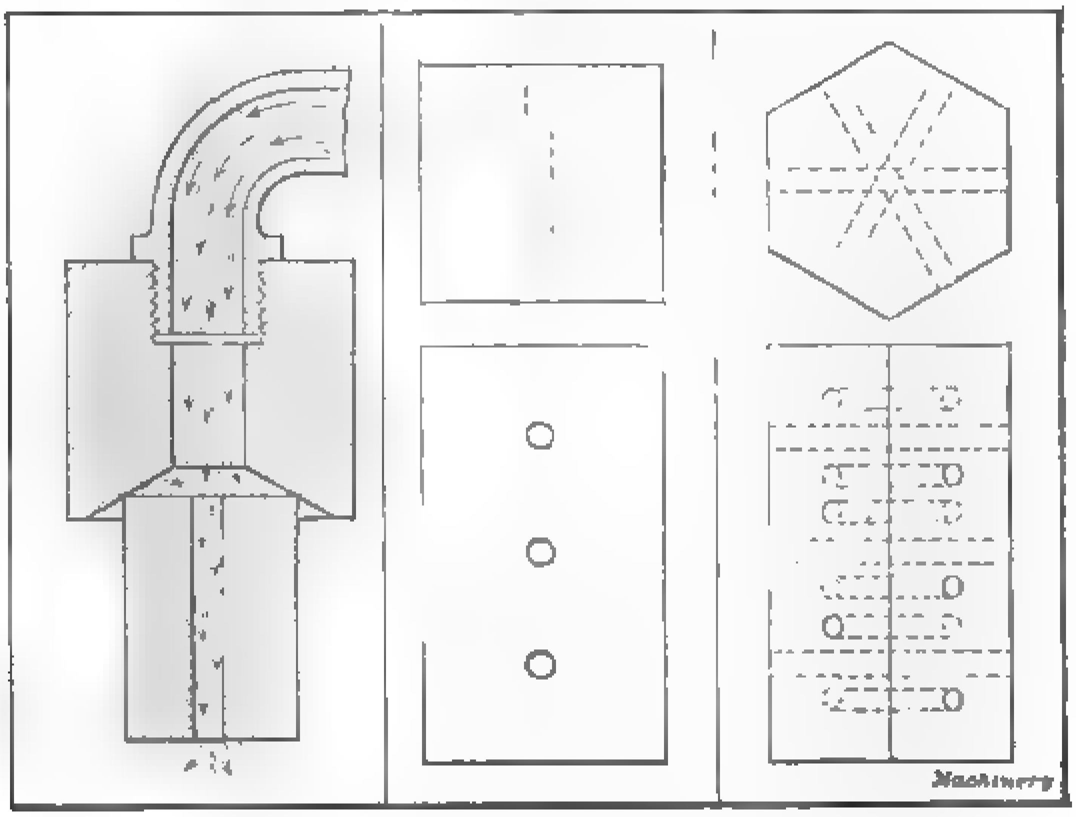


Fig. 44. A Method of hardening Solid Dies

Fig. 45. Multiple Die of Square Type

Fig. 46. Multiple Die of Hexagonal Type

of the die halves, as the cutting is done simultaneously with the movement of the dies. The operations of setting up the punches on the open-die machine are the same as on the solid-die machine.

Special Ball-heading Machinery

The E. J. Manville Machine Co. makes a special type of header adapted for forming ball blanks. The cold-header is an important adjunct to ball making. The principal feature is positive ejection for the ball blanks after heading, because ball headers operate at a very high rate of speed and positive ejection is absolutely necessary. A secondary advantage of this machine lies in its ability to handle positively the short ball blanks.

Fig. 47 shows a vertical longitudinal section taken through the working parts of one of these special ball headers. *A* is the frame or bed of the machine; *B* is the die-block of steel; *C* is a hardened tool

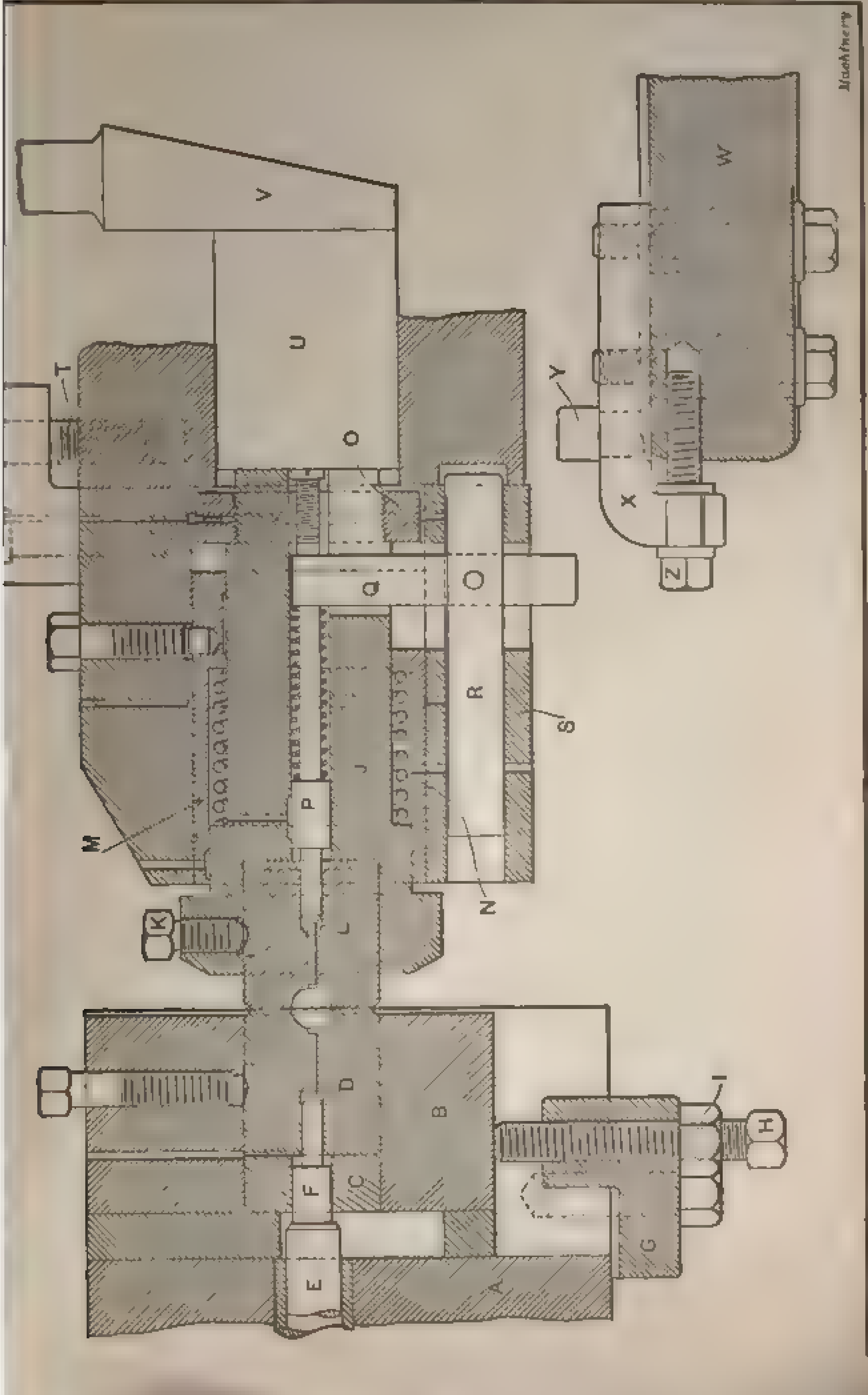


Fig. 47. Special Ball header Tools

steel backing block for the die D; E is the backing or knock-out pin which backs up the smaller knock-out pin F; G is a cast-iron bracket screwed onto the under side of the bed to hold the adjusting screw H which raises or adjusts the die-block into the correct position for heading. A lock-nut I insures the adjustment. J is a tool-steel punch-holder having an enlarged head with a set-screw K for holding the punch L. The body of this holder is of smaller diameter than the head and is made a sliding fit in the bushing M. The holder is normally kept in its forward position under spring tension by means of the coil spring N. Two adjusting nuts O are on the back end of the holder. P is a small hardened tool-steel ejector pin, which is also kept under a spring tension, and is backed up by the bar Q that passes through the round rod R and is pinned in place. S is the punch-slide that carries the punch-holder and other parts shown and is adjusted by the screw T. The punch-holder is backed up by a solid block U that acts as a buffer as well as a filler between the holder and adjusting wedge V. W is a bar cast in the bed between the two sides carrying the adjustable bracket X that has the stop-pin Y and adjusting screw Z.

The action of the machine is as follows: The round bar or wire is fed in and cut off in the usual manner, and the cut-off blade carries a blank over to the heading die, but as there is no shank to be pushed into the die, as is the case with a longer blank or rivet, as soon as it is carried over, the gate or ram advances, and also the pin F. As pin P is under a spring tension the blank is very quickly seized between the two pins, and held in position until the gate has advanced far enough to hold and squeeze the blank into a ball.

After this the gate returns and when it has reached a certain position the bar or trigger Q strikes the pin P that acts as a knock-out, and ejects the ball if it clings to the punch; if it clings to the die the other ejector pin F ejects it.

It will be noticed that the pins F and P are not long enough to reach to the ball arc when under the heading pressure; this leaves slight projections on the two sides which can be removed easily, whereas if the pins were even slightly too long there would be flat spots left on the finished balls.

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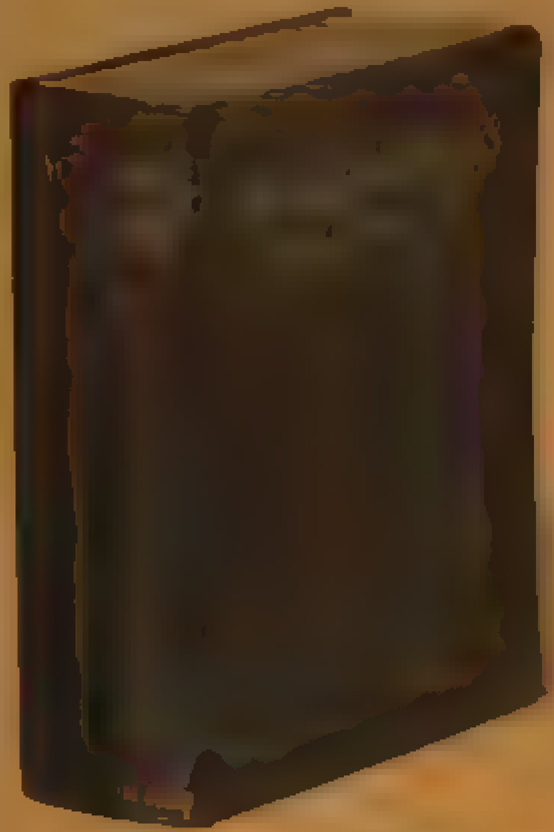

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ARBORS AND WORK-HOLDING DEVICES

CONTENTS

CHAPTER I

HOLDING DEVICES FOR FIRST-OPERATION WORK

The methods of holding and clamping rough castings for the first or chucking "operation" are so diversified that the subject must, necessarily, be treated by means of examples representing different varieties of work. Nearly all of the examples shown are more or less cylindrical in shape, for the reason that elliptical, rectangular, or odd-shaped parts require special treatment and, therefore, can only be touched upon in an article of this kind. In the general course of manufacturing, there are occasionally pieces of peculiar shape which require chucking fixtures, but as this work is of such great variety, it is difficult to give much information regarding its handling except in a general way. Any piece of work of peculiar shape requires a thorough knowledge of the conditions governing its use, in order that it may be chucked properly and located from the surfaces which are of the greatest importance.

Important Points in Design of Chucking Devices

In the design and construction of chucking devices, there are a number of points to which the most careful consideration must be given In some cases, the work must be held by the cored interior, as, for example, an automobile piston, or, in fact, any other work in which it is necessary to have an equal division of metal throughout the cylindrical walls. In other instances, however, some method of exterior holding may be perfectly satisfactory The term "exterior holding" does not necessarily mean that chuck-jaws are referred to, for various devices other than jaws will be cited during the following discussion of holding methods.

Having determined whether the work is to be held externally or internally, let us take up the important points in the design of holding devices

First: The important locating surfaces should be carefully considered, always having in mind the future handling of the piece in its various operations. Great care should be taken that no locating points are so placed that they will come in contact with the work in places where the pattern is gated, or where numbers or letters may appear.

Second: In setting up a rough casting there should never be more than three fixed supporting points; any others which may be necessary for the proper support of the work must be made adjustable, with some approved method of clamping securely after adjustment.

Third: The work must be firmly secured so that no distortion can take place under the strain of clamping

Fourth: When the work is of such a nature that diffic enced in obtaining proper clamping surfaces, it is somet

to consult with the patternmaker in regard to the addition of clamping lugs to the pattern. In cases of this sort, these lugs should be so applied that their subsequent removal can be effected readily.

Fifth: In designing a chucking fixture the safety of the operator should be considered carefully, and by that is meant that protruding heads of screws, bolts, clamps and similar parts should be avoided as much as possible. A little forethought in this regard may be the means of saving an operator from mutilation or death.

Sixth: Convenience and accessibility in setting, locating and clamping the work, are also of primary importance.

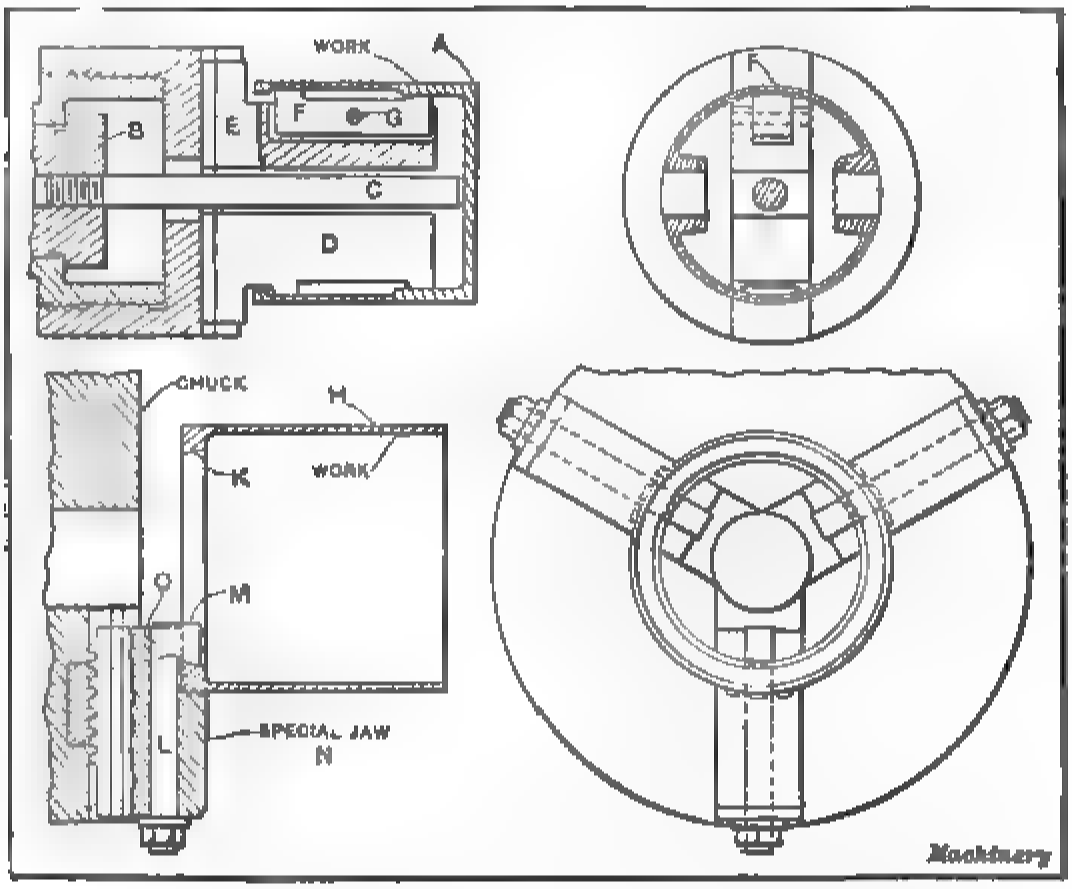

Fig. 1. (Upper View) Two-jawed Chuck for holding Piston internally; (Lower View) Chucking Fixture for Piston Ring Pot

Individual points regarding the work-holding devices shown in the illustrations will be discussed. We shall consider holding devices for the horizontal turret or chucking lathe, the vertical turret lathe, and the vertical boring mill. In describing these devices, the work and its requirements will be considered, as well as the important locating surfaces, the method of handling the work and important points in the design of different fixtures.

Two-jaw Chuck arranged for Internal Chucking

It is essential that the cast-iron piston shown in the upper part of Fig. 1 be located from the cored interior, in order to have the outer walls concentric with the core, thus obtaining an equal distribution of metal throughout the piston walls. Due to the formation of this casting, the core is poorly supported at the closed end and, therefore, has a tendency to drop slightly when the metal is poured into the

mold, thereby producing a lack of concentricity between the cored portion and the exterior surfaces. It is logical then, in order to obtain uniform results, to work from the cored portion when setting up the casting. Many methods of holding have been devised for this purpose. The fixture shown in Fig. 1 is one of the simplest, an ordinary two-jaw chuck with special internal jaws being used for holding and locating the work *A*. A steel bushing *B*, fastened into the spindle, contains the stop-rod *C*, which comes against the head of the piston, thus insuring a uniform thickness of metal at this point. The chuck is supplied with the two special jaws *D* and *E*. The former is a plain jaw with two bearing points, while the other has a swivel-jaw *F*, pivoted on the pin *G*, which allows it to conform to the inequalities of the casting. This method of chucking is one of the cheapest, and the results obtained by its use are fairly satisfactory. There is a tendency toward inequality in the thickness of the piston walls in the direction of the wrist-pin bosses, due to the fact that the centering action of a chuck of this type is in two directions only; however, at least one large manufacturer in the East uses this method entirely. The chuck is employed for rough-turning only, thus securing a partially finished surface which is true with the core and which may be used to work from for subsequent operations.

The work *H*, shown in the lower view of Fig. 1, is a cast-iron piston ring pot, which must be held in such a way that it can be bored, turned eccentrically, and separated into narrow rings for a gas engine piston. As the ring pot is very thin, it must be carefully held to avoid distortion and yet be very rigidly secured, as there are several tools working at one time so that the torsion produced by the cut is excessive. The pot is made with an internal gripping ring *K*, which is slightly beveled to assist in keeping it back against the chuck jaws. The chuck is an ordinary three-jaw, geared-scroll type, having jaws as shown in section at *N*. These jaws are of steel and are drilled to receive the hook-bolts *L* which pass entirely through them and grip the ring from the inside. The heads of the bolts *M* come out through slots in the jaws, the heel having a backing at *O*. When setting a casting the bolts are left free while the jaws are brought up against the outside of the casting with just enough pressure to get a bearing. The bolts are then set up tightly on the gripping ring, so that the work is held firmly but without distortion. This method is very good and can be applied successfully to many varieties of thin work. The hook-bolts are of tool steel and are hardened and drawn to a deep straw on the hook end. The backing up of the hook-bolt at *O* is very important, for unless properly supported at this point its action is greatly impaired and it soon becomes bent out of shape and is absolutely useless.

Ring Pot locating Fixture without Chuck-jaws

Another cast iron ring pot of somewhat different form is shown in Fig. 2. The operations on this piece are identical with those for the

casting shown in the previous illustration, but the holding method is entirely different. This form of pot is used by one of the largest manufacturers in this country. Before it is placed in the fixture, the face of the gripping ring *A* is ground square with the outside of the pot. The body of the fixture *B* is of cast iron and is screwed fast to the spindle nose of the horizontal turret lathe upon which it is used. The annular ring or pad against which the ring pot lies is faced square in position on the machine. A hardened and ground tool-steel bushing *C* is accurately fitted to the inside of the spindle and is held in position by the teat-screw *D*. It will be noted that this bushing also acts as a guide for the boring-bar pilot *E*. A tapered plunger *F* is forced outward by the spring *G* and centralizes the inside of the

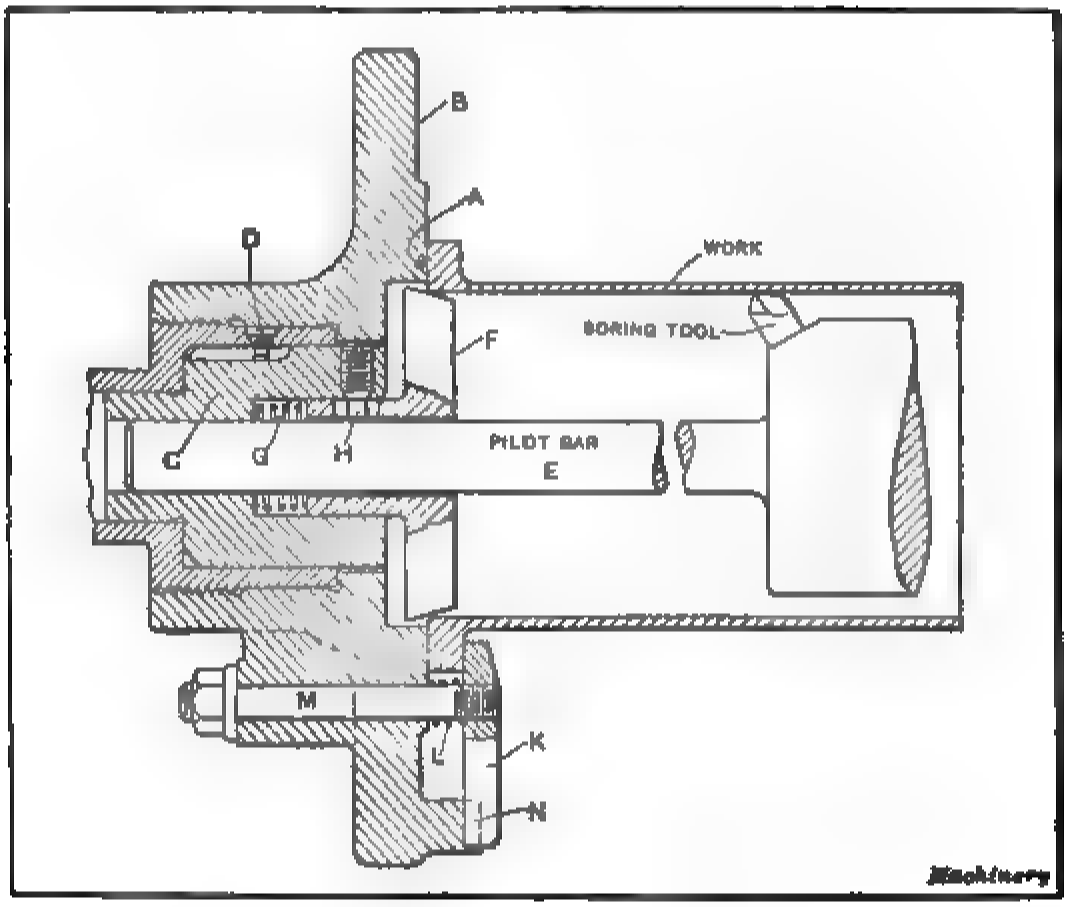

Fig. 2. Another Ring Pot Chucking Fixture

pot. The screw *H* simply acts as a retainer to keep the plunger in position. There are three clamps, 120 degrees apart, on the face of the fixture. One of these is shown at *K*; obviously this is tightened by the screw *M*, while the coil spring *L* serves to keep the clamp away from the work when not in use. The lug *N* prevents the clamp from twisting around when the screw is being tightened. This fixture is a very good one, except that its operation is rather slow.

Locating Fixture for a Ball-and-socket Pipe Joint

The requirements for the work shown in Fig. 3 need little explanation. The piece itself is a steel casting. A cast-iron "cat-head" or fixture *A* is screwed onto the spindle nose, and is faced at *B* to an arc corresponding with the rough ball-portion of the pipe joint. The two

hook-bolts *C* obviously grip the work from the inside and hold it firmly against the finished face *B*. A centering plug *E* fits the turret hole and is brought up and entered into the casting before the hook-bolts are set up tightly. This fixture was not entirely satisfactory owing to the condition of the rough castings at the end *F*, for at this point they varied greatly and were very rough, making the holding somewhat uncertain. A method of holding this work by the interior undoubtedly would have been more satisfactory.

Chucking Device having an Outboard Supplementary Bearing

The automobile tail-shaft housing shown at *B* in Fig. 4 is made of malleable iron and is so long that chucking by means of jaws is out of the question, on account of the excessive overhang which would be

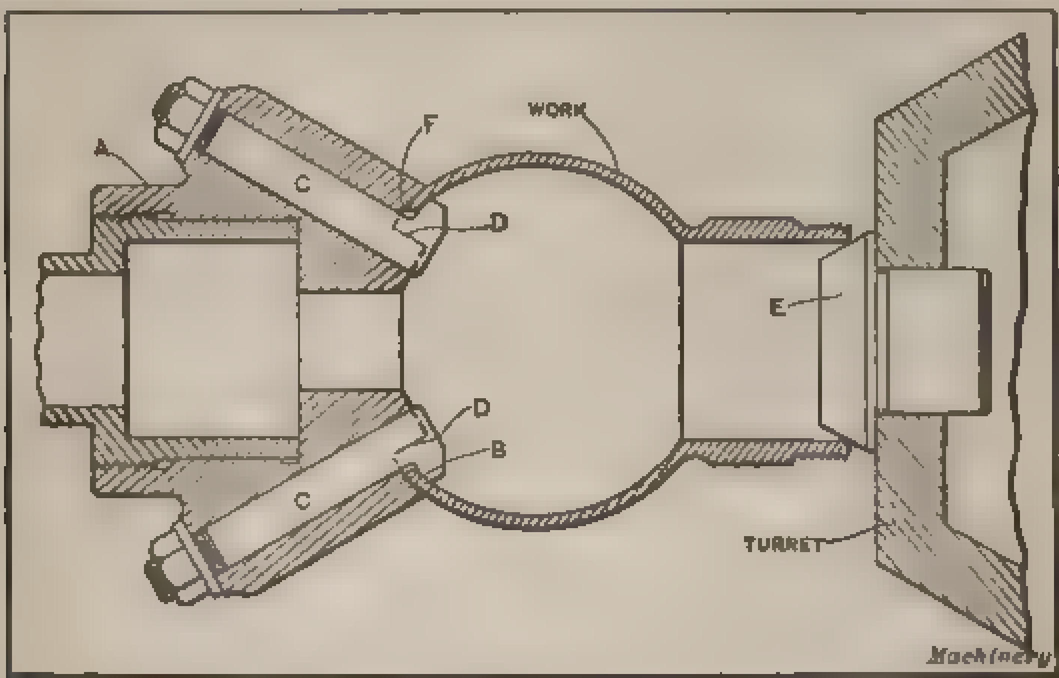

Fig. 3. Fixture for Ball-and-socket Pipe Joint

necessary. The piece was to be finished complete in one setting and the fixture shown was designed and used for this purpose. The body *C* is of cast iron and is screwed onto the spindle nose The inner cylindrical surface *D* is very carefully bored and the outer bearing surface *E* is turned and finally lapped to a nice running fit in the bracket *A*. The periphery *H* of the locating and centering bushing *F* is crowned on a radius and is slotted in various places, as shown at *K*, to receive the exterior ribs on the housing. A pointed set-screw *G* keeps the bushing in position. The tapered plug *L* is located in the turret hole and serves to center the work, and the pointed set-screws *M* (three of which are used) are sunk into the casting and act as drivers in addition to holding it in the position determined by the tapered plug The bracket *A* (also shown in detail) acts as an out-board bearing for the long body of the fixture and prevents the vibration which would other[illegible] [illegible]om the excessive overhang A glass oil cup was an [illegible] [illegible]o the equipment and may be noted at *N*.

Method of Chucking One-half of a Rear-axle Housing

The male portion of an automobile rear axle housing is shown in Fig. 5. This is machined in one setting on a horizontal turret lathe. The body of the fixture *B* is of cast iron and is screwed onto the nose of the spindle. Three steel pins *C* are located 120 degrees apart, around the inside of the fixture body, the coil springs *D* forcing them outward and the set-screws *E* securing them in place when properly located against the work. The method of clamping is somewhat peculiar and should be carefully noted. The swinging dogs *F* have a knife-edge at *K* and are pivoted on the pins *G*, which are set back in such a position that the action of the dogs (controlled by the hollow set-screws *H*) has a tendency to carry the work back against the body of the fixture and the spring jack pins. A steel bushing *L* is forced onto the small end of the work and assists in centering it in the spindle. This bushing is crowned on a radius the same as that shown in Fig. 4. The taper locating plunger *N* is forced out by the spring *O* and is restricted in its action by the pin *P*. The two-arm support *Q* is of cast iron and is of assistance in keeping the work in position while the various screws and dogs are being tightened. The bushing *M* acts as a guide for the boring-bars and reamers used in machining the work The work is driven by the ribs *R*, which enter slots in the body of the fixture. This method of holding gave satisfactory results, although considerable care was necessary to avoid springing the casting when tightening the clamping dogs.

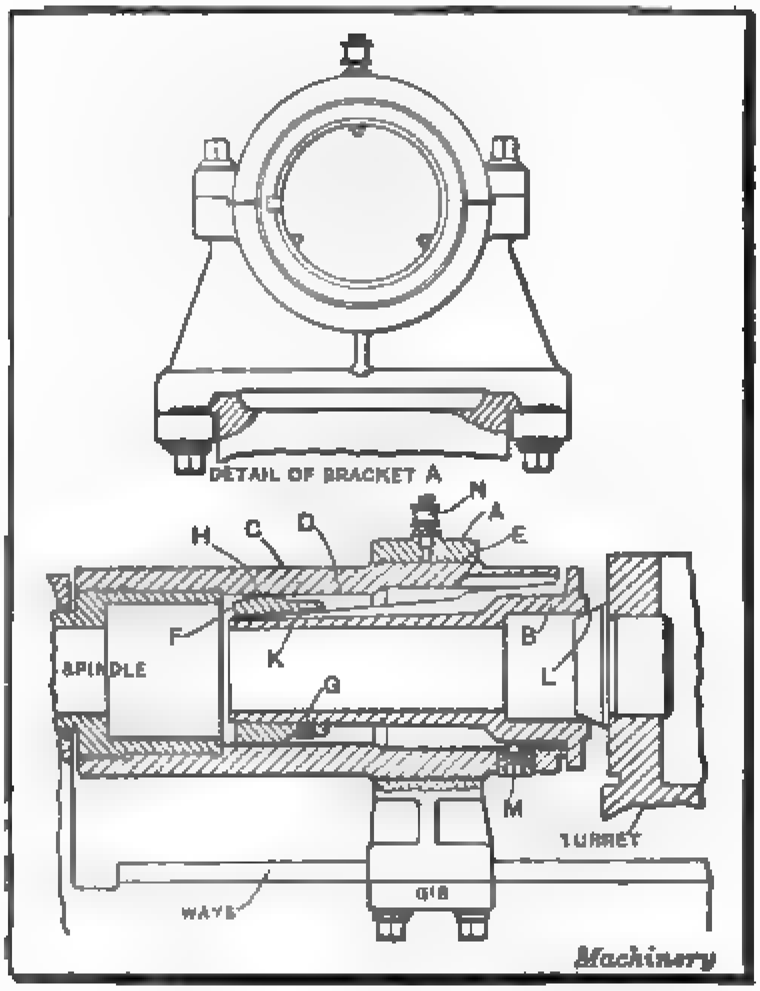

Fig. 4. Fixture for holding a Long Part—Outer End is supported by Bracket

Equalizing Pin Chuck for a Gas Engine Piston

One of the many varieties of internal holding piston chucks is illustrated in Fig. 6. Although rather expensive, it is an excellent example of this type of chuck, and is very well made. All working parts are of steel or bronze and all parts requiring such treatment ar carefully hardened and ground. The body of the chuck is of a

chine steel, carbonized, pack-hardened and ground; the pins, cams, operating rod, screws and bushings are of tool steel; while the miter gears are of bronze. The body of the chuck *A* is screwed onto the spindle nose and is ground or lapped at all important points. The operating cams *B* and *C* are slotted in three places around the periphery at *D* and *E*, these slots being angular and forcing the six pins *F* and *G* out against the interior walls of the piston. It may be noted that the steel plates *H* and *K* are let into the body of the chuck, and act as retainers for the pins. These plates are clearly shown in the upper view. The operating rod *L* is revolved through the action of the miter gears *M* and *N*. The latter has a key *T* engaging a long spline in the operating rod, which is thereby permitted to move longitudinally. The threaded portion *U* is 6-pitch right hand thread, while that at *V* is 6-pitch left-hand thread. The forward cam is packed with felt at *X* to keep out the dirt. The bushing *O* is of tool steel, hardened and ground. The plug *Q* simply closes the hole which has been put in for assembling purposes.

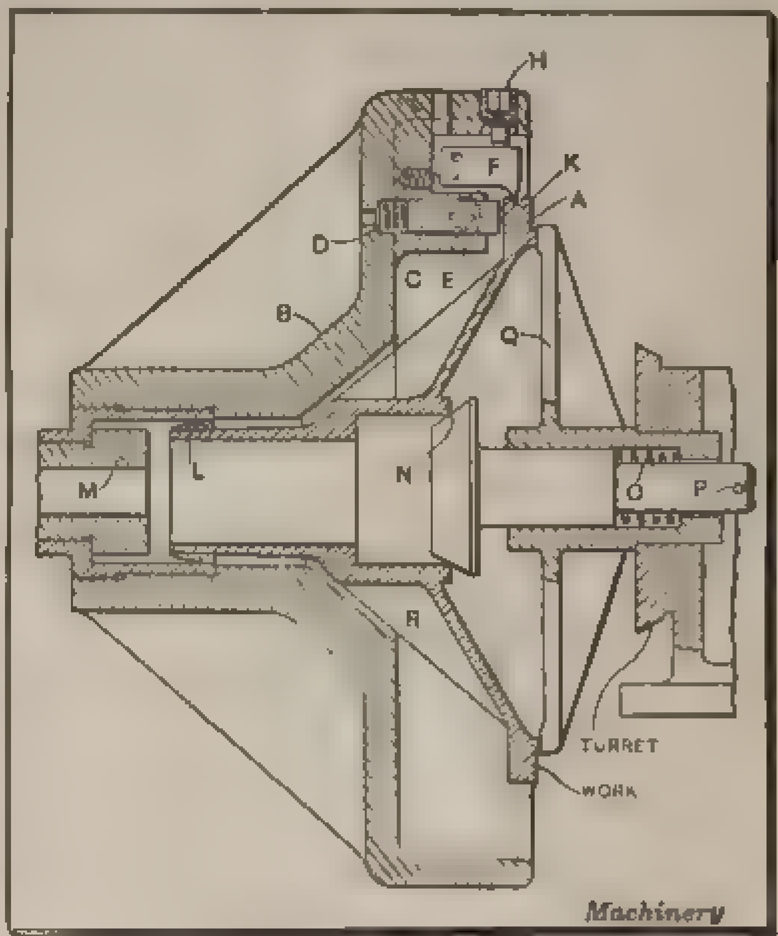

Fig. 5 Casting A held so that it can be machined at One Setting

By referring to the upper view it will be seen that the chuck body is cut away on the sides at *R* and *S*, on account of the wrist-pin bosses in the piston, and the overhanging lip at *R* acts as a driver. In designing a chuck of this kind, it must be remembered that while the rear clamping pins may be equally spaced, the position of the forward pins will be determined by the diameter and spacing of the wrist-pin bosses, and an end view will be found essential to determine the correct position. In general it will be found that two of the forward pins seldom can be spaced more than 80 degrees apart and often the spacing cannot be made more than 55 or 60 degrees. Another point in design which is of great importance is the amount of clearance between the ends of the wrist pin bosses and the flattened sides of the chuck body. It is seldom safe to allow a clearance of less than 3/16 inch on each s[illegible]hed sizes called for on the drawing

of the piston. The location of the stop-pins *W* is also important, and sufficient allowance should be made in the length of the cam slots to take care of variations in the piston castings. A chuck of this type gives results which are satisfactory in every respect.

An Equalizing Pin Chuck for an Electric Generator Frame

The examples which have been referred to in the foregoing are all adapted for use on the horizontal type of turret lathe, but we shall now go a step farther and take up chucking devices designed for the vertical turret lathe and the vertical boring mill. As machines of this type are adapted more to heavier classes of work, the fixtures

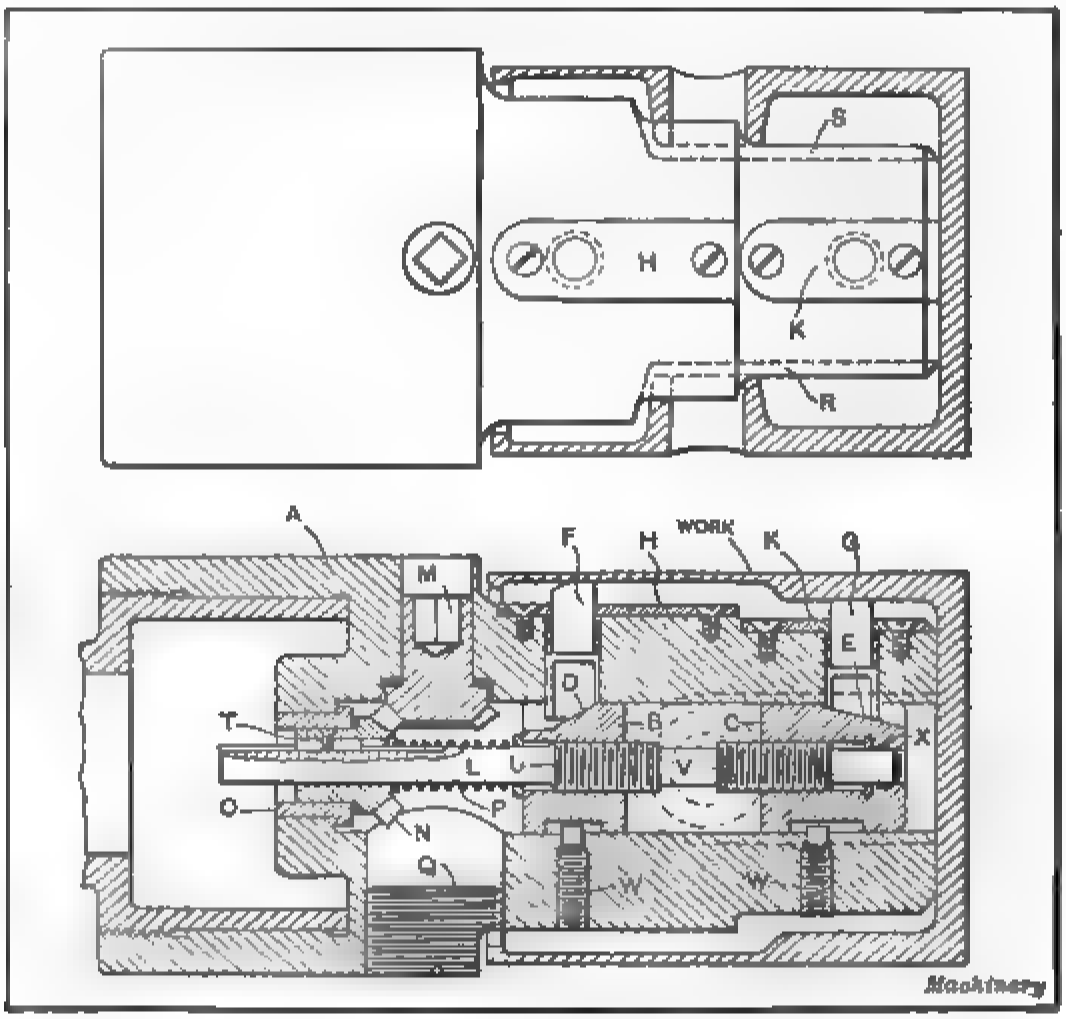

Fig. 6. Special Chuck for holding Gas Engine Pistons internally

should be designed with relation to the work and also to the power of the machines upon which they are to be used. For machining the steel generator frame shown on the fixture in Fig. 7, the working points specified by the manufacturer are at *B* between the ribs *C* on the upper portion of the casting *A*. It was further specified that the work must be held by the core to insure an evenly balanced casting.

The design of this chuck resembles that shown in Fig. 6, in that both chucks are fitted with pins and operating cams; the operating mechanism, however, is entirely different. The body of the chuck ... *D* is of cast iron; it is carefully reamed and lapped at im points, and is securely fastened down to the table of the by three screws having tee-shaped heads, which enter the t

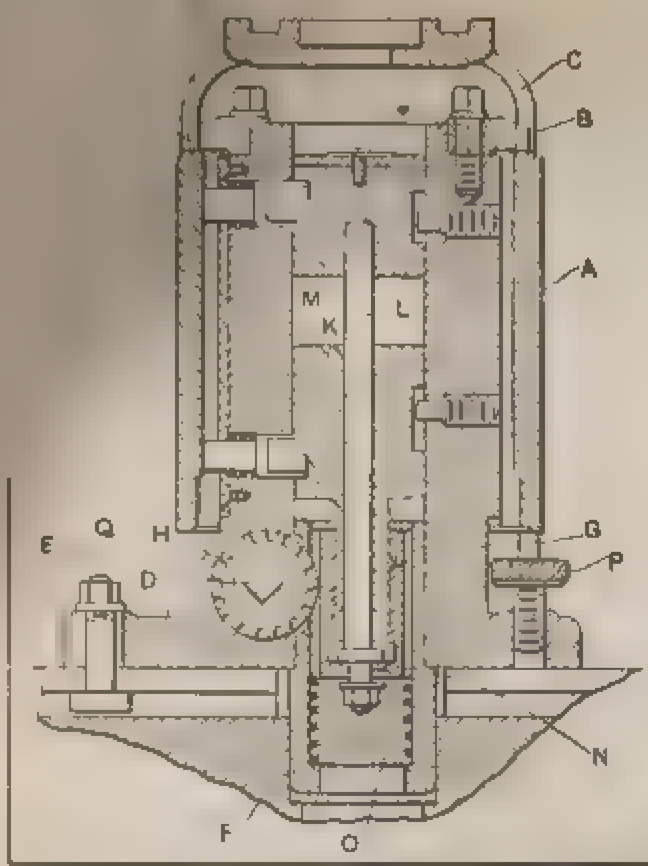

Fig. 7. Vertical Boring Mill Fixture for holding Part A internally

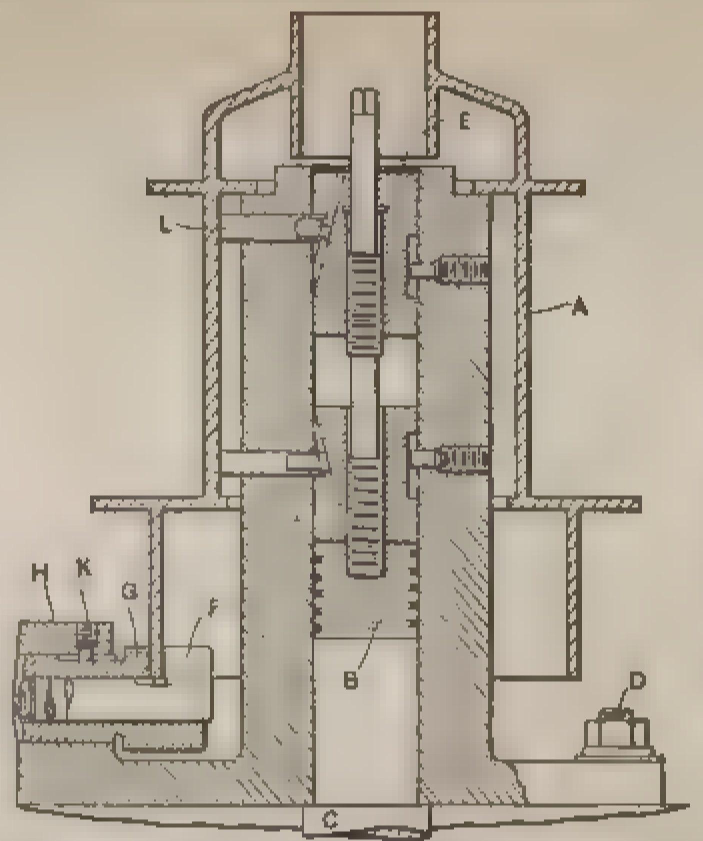

Fig. 6. Vertical Fixture having Internal Clamping Pins and Hook-bolt Clamps for Lower Flange

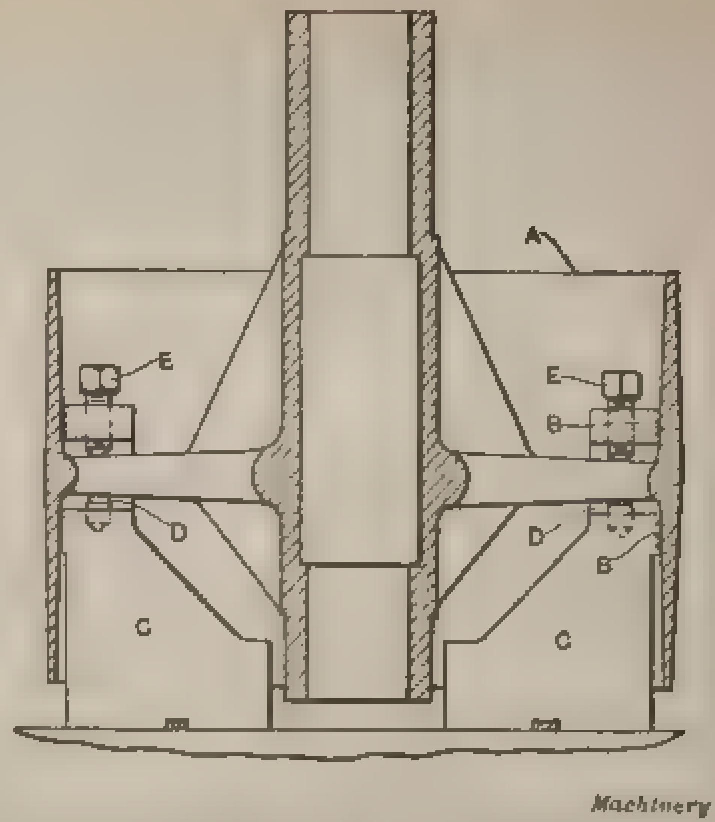

Fig. 9. Special Chucking Jaws for Large Pulley

as shown at E. The fixture is centered by the hollow stud F, which is of tool steel, hardened and ground inside and out. This stud also acts as a bushing for the operating sleeve G and is cut away for clearance on one side where the spiral gear H passes through it. This gear meshes with another which is cut on the outside of the operating sleeve. The latter is of bronze and it is threaded internally with a 6-pitch Acme thread, corresponding with that cut upon the lower end of the cam K. The operating rod L is pinned into the upper cam M and is shouldered and journaled at its

lower end where it passes through the operating sleeve at *N*. The coil spring *O* is so proportioned that it simply supports the cam mechanism and assists in releasing. It will be noted that the arrangement of this internal mechanism permits a "floating" action for the cams, so that the clamping pins all bear uniformly against the inner walls of the casting. In setting up the work on the fixture, it is dropped over the top until the lower end rests on the three adjusting jacks *P*, which are placed 120 degrees apart and are knurled for finger adjustment. The upper locating arms *B* are swung back out of the way while the casting is being set in position, but as soon as this has been done they are brought around into the position required. The jacks are next raised until the casting has been properly located against the arms; then a long-handled socket wrench is inserted at *Q* and the gearing is revolved until the pins are securely seated against the inner walls of the work.

A Combination Device having Equalizing Pins and Hook-bolts

The piece shown at *A* in Fig. 8 is a clutch pulley for a gasoline tractor. It is made of cast iron and the method of holding from the inside was decided upon because it seemed to offer better facilities for machining. As in a former example, the body of the fixture contains the cams and the operating rod which is threaded right- and left-hand, as before. The lower ends of the pins and the slots in the cams are dovetailed in this instance, so that the outward and inward movements are controlled mechanically, no springs or plates being required. The fixture is centrally located on the machine table by the plug *C*, which fits the center hole in the table and is held down in the usual manner by the T-bolts shown at *D*. The coil spring *B* simply acts as a support for the cams and rod. An annular groove is cut in the upper cam at *E* and this is packed with felt to assist in keeping the dirt out of the working parts. The lower part of the fixture has three bosses (one of which is partially shown at *H*), which contain the floating jaws and hook-bolts, *G* and *F*, for clamping the lower flange of the pulley. The construction of these parts is more clearly shown in Fig. 10, and, as they are identical the reader is referred to the portions marked *C* and *D* in that illustration. The results obtained by the use of this fixture were at first very satisfactory, but, after a time, the dirt which gradually accumulated in the dovetail cam slots, began to cause trouble, until, finally, it became almost impossible to operate the mechanism. Then, too, in several cases the dovetail part broke off completely, necessitating new pins, so that the chuck as a whole cannot be considered an absolute success. No trouble would have been experienced if the cam slots and pins had been made as shown in Fig. 7, with coil springs and retaining plates.

A Set of Special Jaws for a Large Crowned Pulley

The large farm engine pulley shown at *A* in Fig. 9 is of cast and it must be held by the inside in such a way that it will

distorted while fairly heavy cutting is being done on the periphery of the pulley. A four-jaw table was selected on which to hold the work, as there were eight spokes in the pulley. The chuck jaws *C* were made of 0.40 per cent carbon steel and were slotted out for the spokes as shown in the illustration. The hardened steel studs *D* were set into the slots, and the set-screws *E* brought down tightly on them after the jaw surfaces *B* had been brought out to center the pulley.

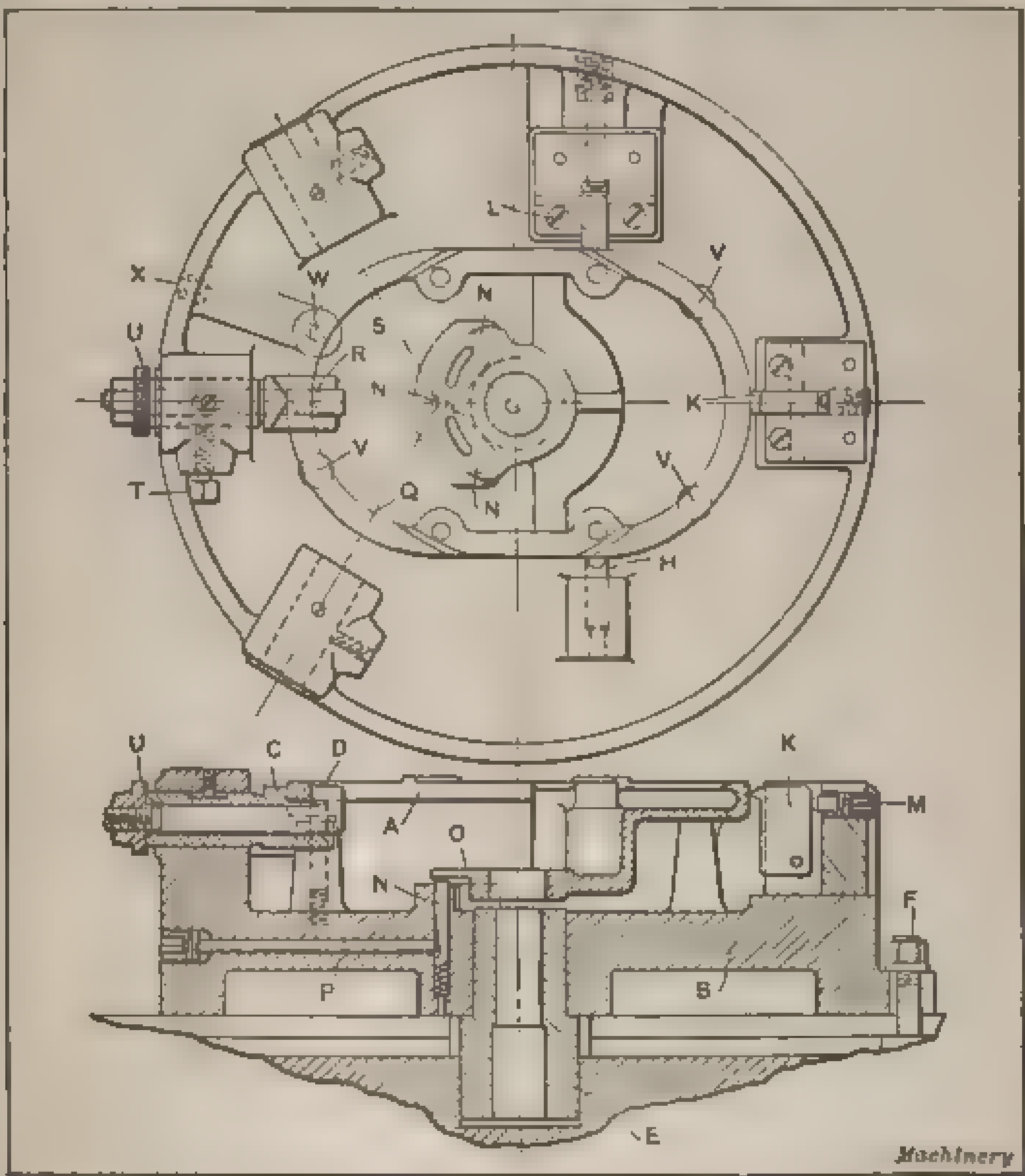

Fig. 10. Ingenious Chucking Device for holding Odd-shaped Aluminum Casting without Distortion

This method of holding pulleys or other spoked work gives very satisfactory results and is used by many manufacturers throughout the country.

A Chucking Device for a Difficult Piece of Electrical Work

The aluminum piece shown in Fig. 10 is one of the most difficult for which there ever is an occasion to make a chucking fixture The walls of the entire piece were of very thin section, and the overhanging portion *A* was elliptical in shape and entirely unsupported. It was nece ld this casting that it could be machined without

distortion. The body of the fixture *B* is of cast iron. It is centrally located on the table by means of the hollow bushing *E*, and clamped down by T-bolts shown at *F* in the table T-slots. A portion of the fixture shown in the upper view at *G* was cut out to form a V, in which the cylindrical portion of the casting is centered. One of the sides of the casting is located against the knife-edged pin *H* (shown in the upper view), and the casting is forced into the V and against this knife-edged surface by the swinging clamps *K* and *L*. It will be noted that these clamps also have a knife-edge and that the pins upon which they are hung are in such a position that their action is downward, thereby tending to hold the work securely against its supports. Hollow set-screws *M* control the action of these swinging clamps. There are three spring-pins *N* which are used to support the very thin flange *O*, and the springs which force them upward are carefully proportioned so that they have just sufficient strength to insure contact without springing the work. These pins are locked in their positions by the long hollow set-screws *P*, shown in the lower view.

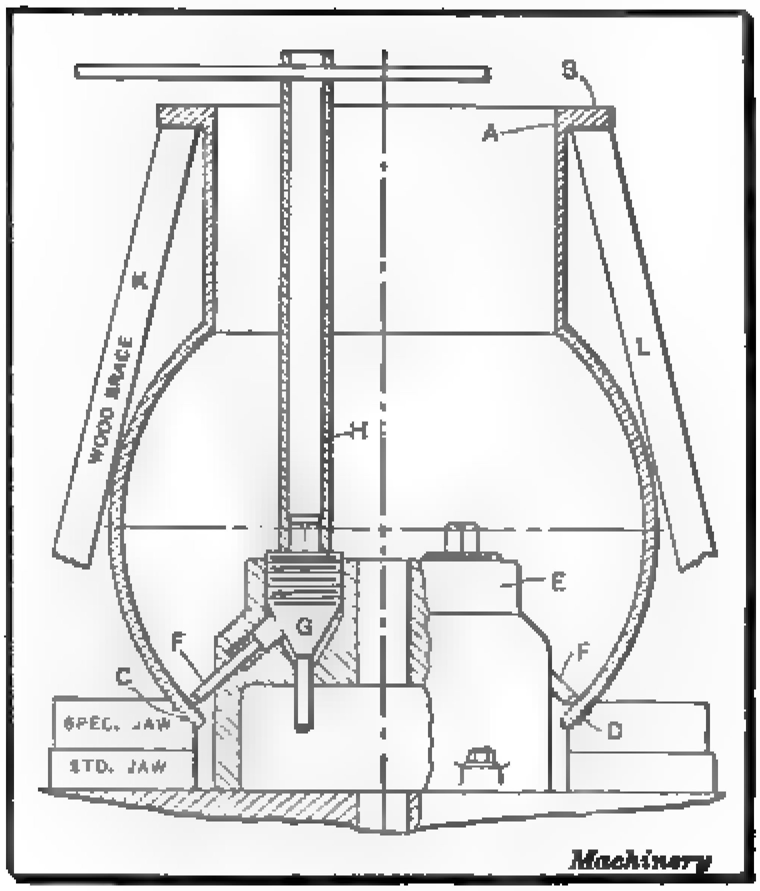

Fig. 11. Vertical Boring Mill Fixture for holding Large Ball Joint

One of the principal points of interest in this fixture is the method of gripping the overhanging elliptical portion *A*, without distorting the casting. This is accomplished by means of the floating jaw *C* and the hook-bolt *D*. There are three of these floating clamps which grip the work at points *Q*, *R*, and *S* (see plan view). It will be noted that the clamps are free to "float" laterally, until the set-screws at *T* are tightened. The knurled hexagon nut *U* is threaded onto the head of the hook-bolt, and is lightly tightened by means of the fingers before the final tightening with a wrench. As these clamps have a perfectly free floating action, until the binding screws are tightened, obviously there can be no distortion of the piece, and yet it is held rigidly at these points. When the work is placed into the fixture it rests upon three fixed points shown in the plan view at *V* and a fourth point *W*. The latter is held upward by a light spring and it is locked in position by the long hollow set-screw *X*.

The work accomplished by the use of this fixture was true and accurate, no evidence of springing out of true being apparent.

Boring Mill Fixtures for a Large Ball Joint

The work shown at *A* in Fig. 11 is a large ball pipe joint for a suction dredge, and it is to be faced on the upper surface *B*. Two designs were made for this work, neither of which was used, but as the conditions are somewhat peculiar the fixtures will be described, and may be taken for what they are worth. The special jaws *C* and *D* are bored to an arc corresponding with the ball, and the work rests upon and is centered by these jaws. The body of the clamping device *E* is of cast iron and is bolted down to the table. It contains four pointed screws *F*, which, normally, are kept away from the work by means of coil springs. The ends of the screws are beveled to the same taper as the operating screws *G*, which are threaded at their upper ends with a coarse pitch thread, and have squares to receive the end of the long socket-wrench *H*, by means of which the screw is revolved, thus causing the points to sink down into the casting. Wood braces are used to support the flange which is to be faced. Four are used, although only two (*A* and *L*) are shown in the illustration. This fixture would have been rather expensive, but doubtless would have produced satisfactory results.

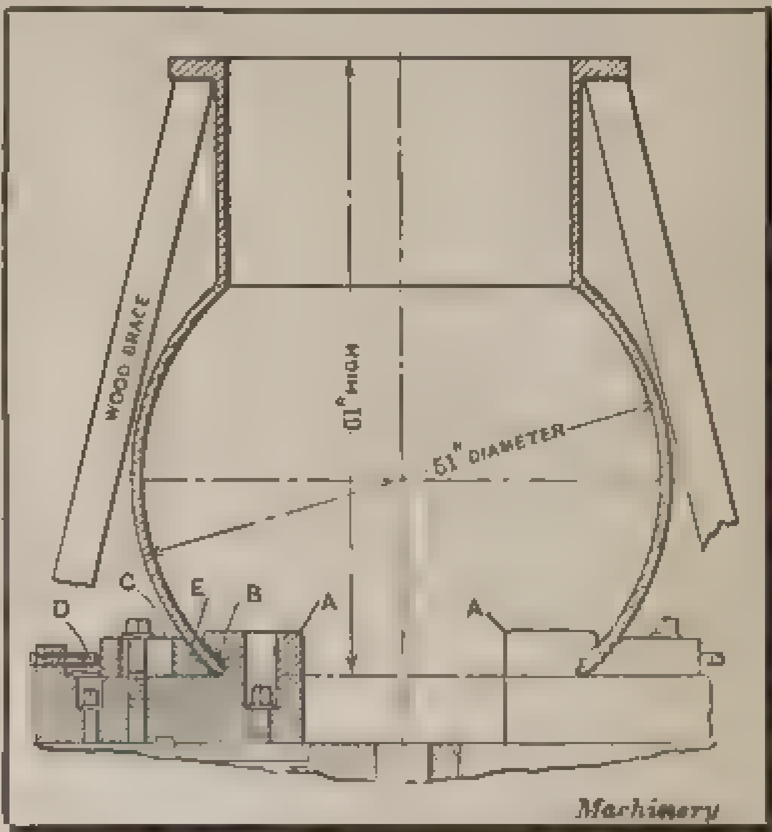

Fig. 12. Another Method of holding Large Ball Joint

Fig. 12 illustrates another fixture for holding the same piece of work, which probably would have given more satisfactory results than the one shown in the previous illustration. It could have been manipulated more rapidly, because it is more accessible to the operator. Four sets of special jaws *A* are used for holding the work. The part *B* is formed to an arc corresponding to that part of the work which it grips, and has teeth to assist in obtaining a firm "bite." The supplementary sliding jaw *C* is forced into position by the set-screw *D*, thus clamping the work tightly between *B* and *E*. Wooden supports are used under the flange.

CHAPTER II

ARBORS FOR SECOND-OPERATION WORK

Cylindrical work which cannot be completely machined in one setting and which requires concentricity of the various surfaces obviously makes necessary some method of holding it for the second operation which utilizes a previously machined surface for securing the proper location. When this surface is external, the use of soft jaws, a step-chuck or collet jaws is feasible, but when an internal surface is the locating point the most efficient method is conceded to be some form of arbor. This arbor may be either a plain stud made to fit the hole

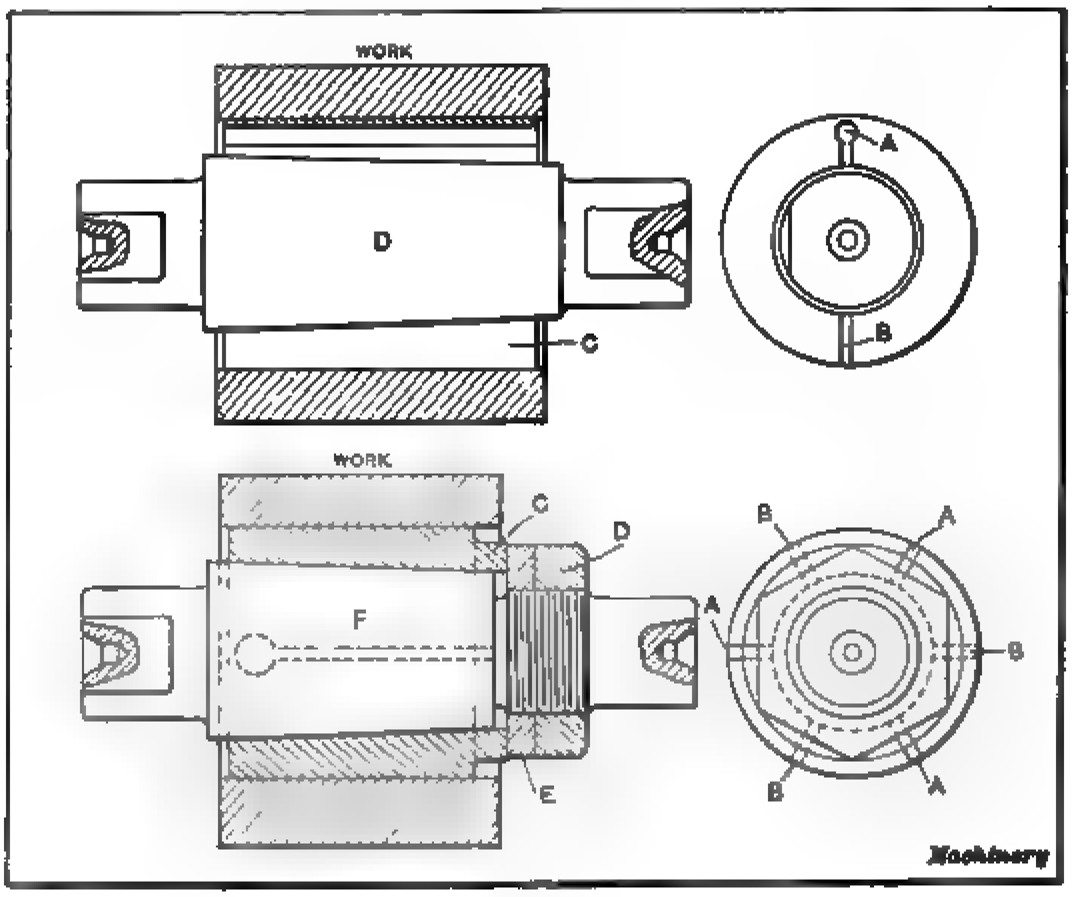

Fig. 1. Two Types of Expansion Arbors with Split Sleeves

in question, or it may be so designed as to be susceptible of a certain amount of expansion and contraction in order to take care of slight variations in the finished hole. The degree of accuracy required in the finished product determines the form of arbor which should be used. If a variation of 0.002 to 0.003 inch in concentricity is permissible, a plain arbor with some method of driving the work will answer the purpose very well. When very accurate work is required, however, greater care must be used in the design, and the expanding type of arbor is commonly used.

Important Points in Design of Arbors

The fundamental features which tend to make an arbor thoroughly efficient are as follows: Expansion must be uniform along the entire periphery; release must be quick and easy, ample driving facilities must be provided, clamping the work must be effected without chance of distortion. As an additional refinement, provision may be made for truing up the arbor so that it will run accurately with the center line of the spindle.

Lathe Arbors

Let us first consider the arbors designed for use in the engine lathe, adapted to be held between centers and driven by means of a dog on one end. The arbor shown in the upper part of Fig. 1 is the simplest of all those which have a split sleeve or bushing capable of expansion

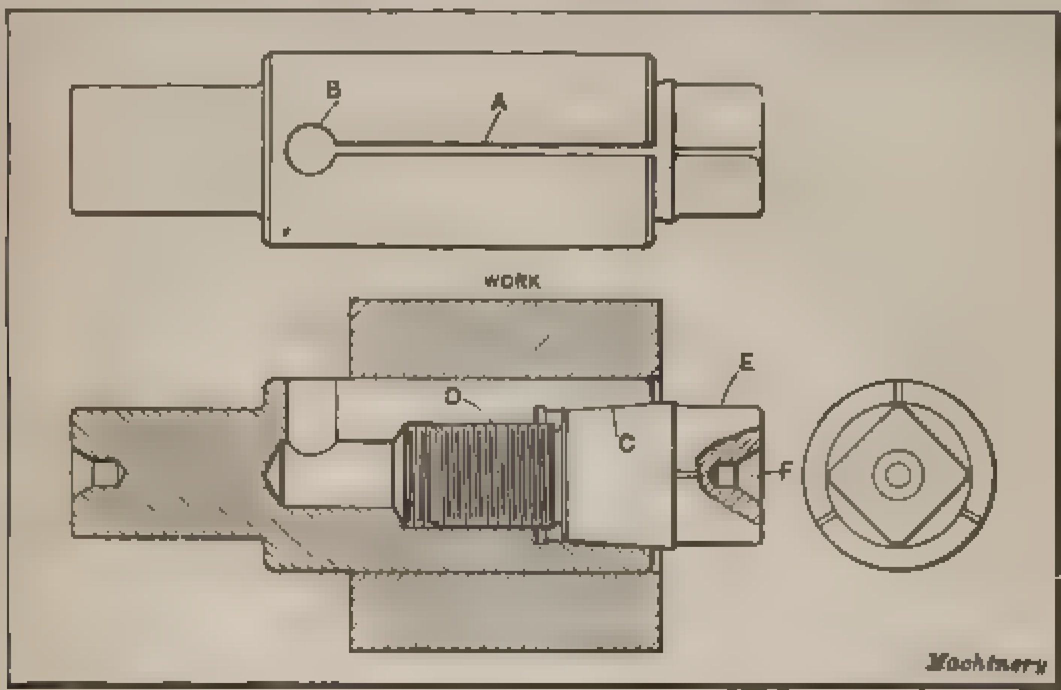

Fig. 3. Arbor expanded by Internal Taper Plug

or contraction. The mandrel D is slightly tapered and is flattened on each end to receive the dog for driving. The sleeve C is correspondingly tapered and is drilled entirely through at A, after which it is saw-cut at B is allow for expansion This arbor is the poorest of all the expanding types in that the expansion is not uniform, being in two directions only, and it cannot be depended upon to give results which are absolutely accurate.

A much better arbor is shown in the lower part of the same illustration. It will be noted that the mandrel F, in addition to being tapered, is threaded on one end to receive the hexagon nut D. This does away with the necessity of using the arbor press to expand the sleeve The collar E is interposed between the nut and the split bushing. This bushing C is saw-cut at A from one end and at B from the other, thus allowing a uniform expansion along its entire periphery. In this connection, it is well to note that the ends of the saw-cuts should be left tied together until after the sleeve has been hardened and ground; they can then be cut apart readily with a thin emery

wheel. An arbor of this kind is mechanically correct and, if carefully made, should give results which leave nothing to be desired as far as accuracy is concerned.

Fig. 2 shows an arbor of a very different type, which might be called a solid expanding arbor. Three holes *B* are drilled 120 degrees apart and the saw-cuts *A* are milled as shown. The special screw *E* is tapered at *C* and threaded at *D* in the body of the arbor. The end of this screw is squared and contains the center *F*. When made as shown there is nothing in this arbor to commend it. In the first place, the expansion takes place at one end only and is not at all uniform, and, in the second place, the center *F* in the end of the screw cannot be depended upon to remain true for any length of time, even assuming that it may have been made reasonably true to start with, which, in itself, is a difficult machining proposition.

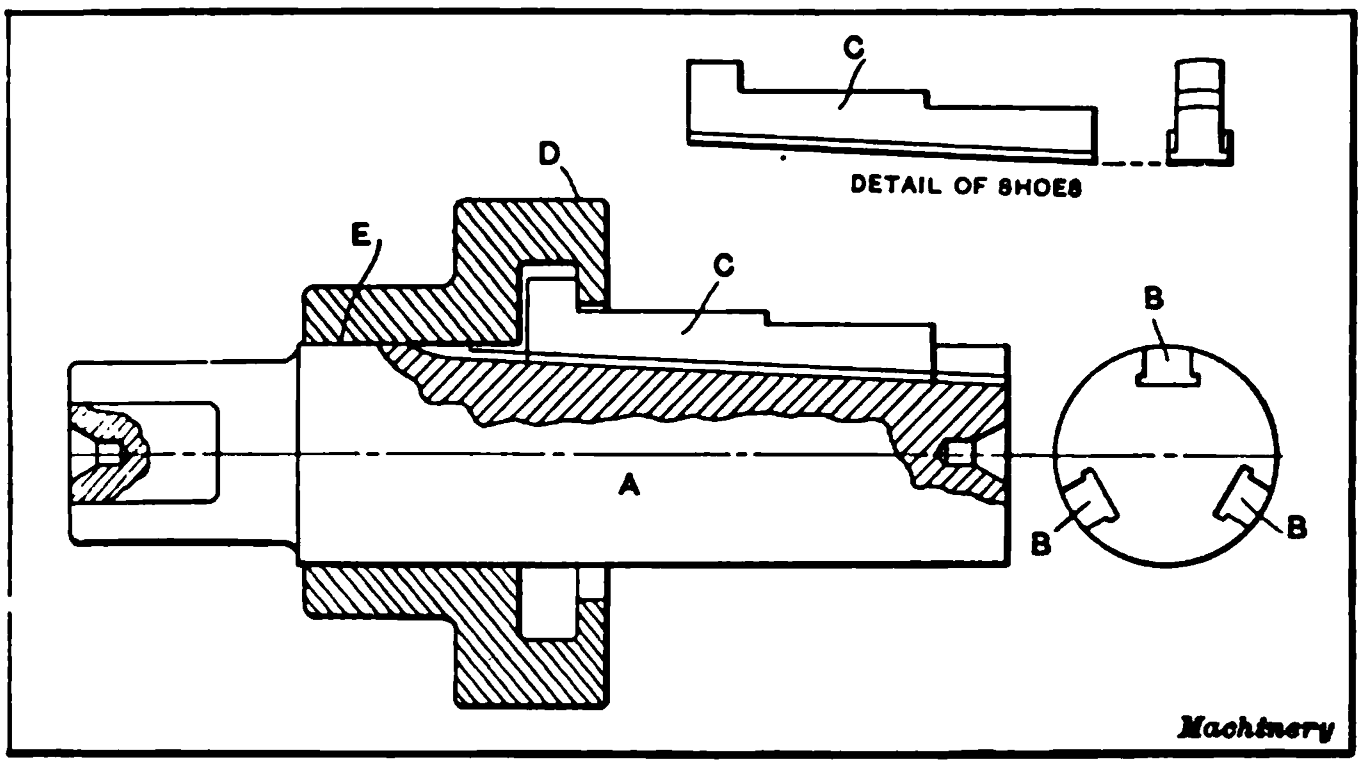

Fig. 8. Expanding Arbor of Sliding-shoe Type

The arbor shown in Fig. 3 was at one time manufactured commercially by G. E. Le Count, South Norwalk, Conn., but the writer is unable to state whether it is on the market at the present time or not. It consists of the body *A* in which are milled the tapered slots *B*. The shoes *C* (also shown in detail in the upper part of the illustration) have a narrow rib running along each side and this rib engages with the grooves in the sides of the slots *B*, thus preventing the shoes from falling out. The collar *D* controls the action of the shoes and is ground to a sliding fit on the cylindrical portion *E* of the arbor. It may be noted that the shoes have two shoulders, thus increasing the range of the arbor. By providing shoes of various diameters the range can be increased considerably.

W. H. Nicholson & Co., Wilkesbarre, Pa., manufacture the expanding arbor shown in Fig. 9 in various sizes and to suit various conditions.. The body *A* is made of tool steel, hardened and ground to a cylindrical form. The centers are exceptionally large and are carefully rounded and lead-lapped after hardening. There are four slots in the body (shown in the section *A-B*), and these slots are relieved at

each corner to prevent any interference by dirt. After hardening, the slots are also ground to insure truth. The jaws *C* (also shown in detail) are made of special steel and carefully ground to the same taper as the slots. After assembling, they are also ground radially on their own arbor. The sleeve *D* acts as a retainer for the jaws and is a running fit on the cylindrical portion *E* of the arbor. Four slots are cut through the sleeve and the jaws are held in position by them. These arbors are too well known to need further comment, as they are in general use throughout the country.

Turret Lathe Arbors

We will now go a step further and take up the type of arbors adapted for use in the horizontal turret lathe. It is well to bear in

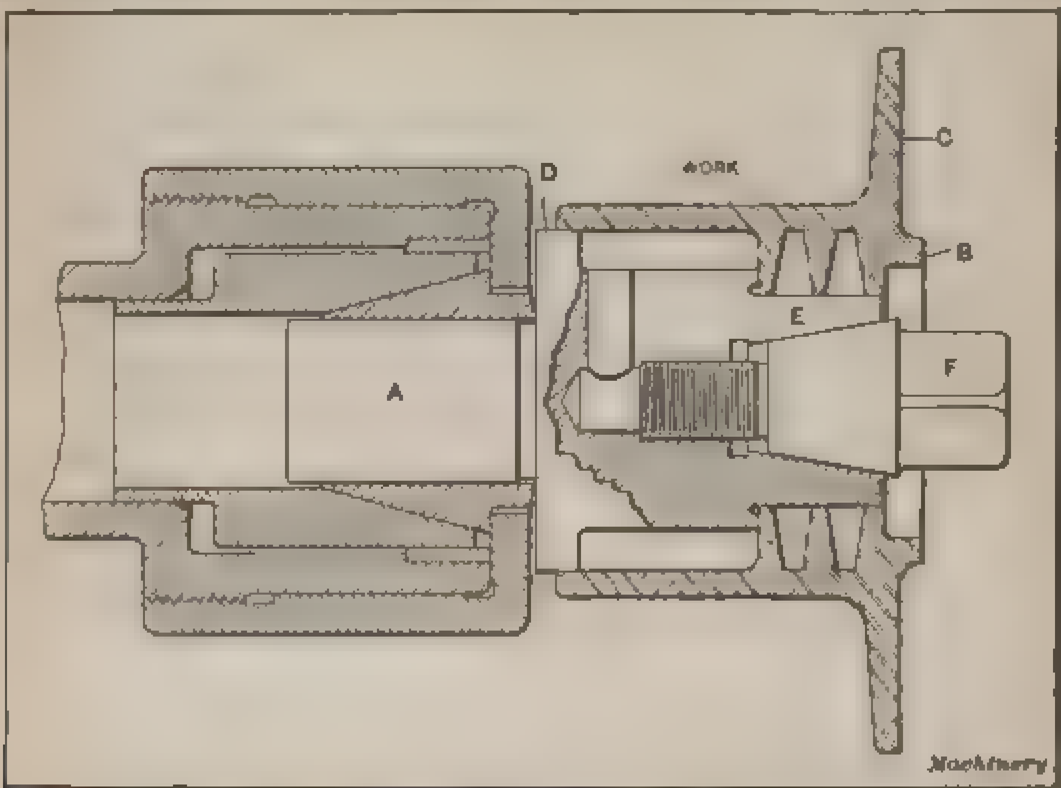

Fig. 4. Arbor held in Collet and expanded by Internal Taper Plug

mind that arbors of this sort should be so designed that the work may be easily and quickly put on and taken off without the assistance of anything more than a wrench or spanner. Every precaution must also be used in clamping and driving the work, so that no chance for distortion is possible.

The arbor shown in Fig. 4 is somewhat similar in construction to that in Fig. 2, except that it is adapted to be held in collet jaws instead of on centers, as in the former instance. This arbor gave satisfactory results on the work for which it was used, the surfaces *B* and *C* being faced within the required limits of accuracy. The work was a push fit on the cylindrical portion *D*, the expansion taking place at *E*, controlled by the tapered screw *F*. In this case, the nature of the work permitted a slight margin of error and the expansion wa[illegible] necessary to prevent chatter and act as a driver. The [illegible] held in the collet jaws.

The arbor shown in Fig. 5 was made for the transmission gear which is shown in position. After the taper hole had been "chucked" in the work (which was done in a previous setting) the keyway *A* was cut for assistance in driving. The arbor body *B* is of cast iron, ground to fit the spindle at *C* and *D*. The stem *G* is of steel, hardened and ground to fit the body, into which it is keyed to resist the torsion of the cut. It is held in position and drawn back by the nut and collar *L* and *M*. The forward end is ground to the correct taper *E*, and the key is inserted at *A*. The portion *F* is threaded with a six-pitch Acme thread, right-hand, and the nut *H* is used,to remove the piece after the work is finished, a piece of drill rod being used in the spanner hole *K* to turn the nut. The screw *N* prevents the body from turning in the spindle. This arbor has given very satisfactory results.

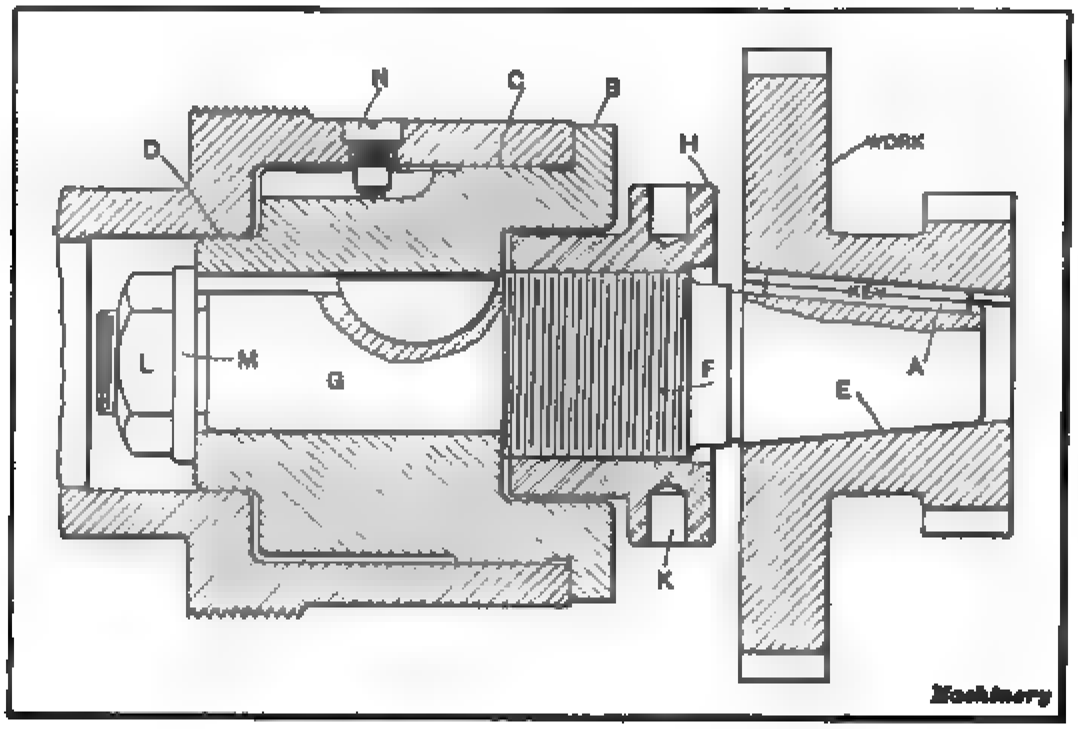

Fig. 5. Taper Arbor mounted in Spindle and equipped with Nut for removing Work

A somewhat extraordinary condition is shown in Fig. 6, which illustrates a steel automobile hub and arbor. In this case, the bearing seats at *A* and *B* were required to be absolutely concentric. In order to assist in machining, the portion *C* was bored to size in the first setting, although no finish was required at this point. The body of the arbor *D* is of tool steel, hardened and ground at all important points. The small end is slotted at three places as shown at *F* and is spring tempered at this end. The operating rod *K* has a very free thread at *H* and is ground to a snug running fit in the cylindrical portion *G* to insure true running, regardless of the condition of the threaded part. All the tools used on surface *B* of the work were piloted by the stem or extension of rod *K*, thus securing absolute truth and concentricity of the ends *A* and *B*.

There are several important points to be noted in the construction of this arbor. First, the method of obtaining a true running stem or

extension of rod K by means of the long cylindrical bearing at G; second, the use of the stem as a pilot for tools, thereby obtaining concentricity in the two ends of the work A and B; third, the positive location of one end at A, while using an expansion principle at the other end to insure rigidity and freedom from chatter. This arbor was very satisfactory, the two ends being within the extremely narrow limits of concentricity required.

An entirely different type is illustrated in Fig. 7. This is used for two different sizes of bronze bearing retainers, the use of adapters making this feasible. In the construction of this arbor, the body A is screwed directly onto the spindle nose, bringing up snugly against

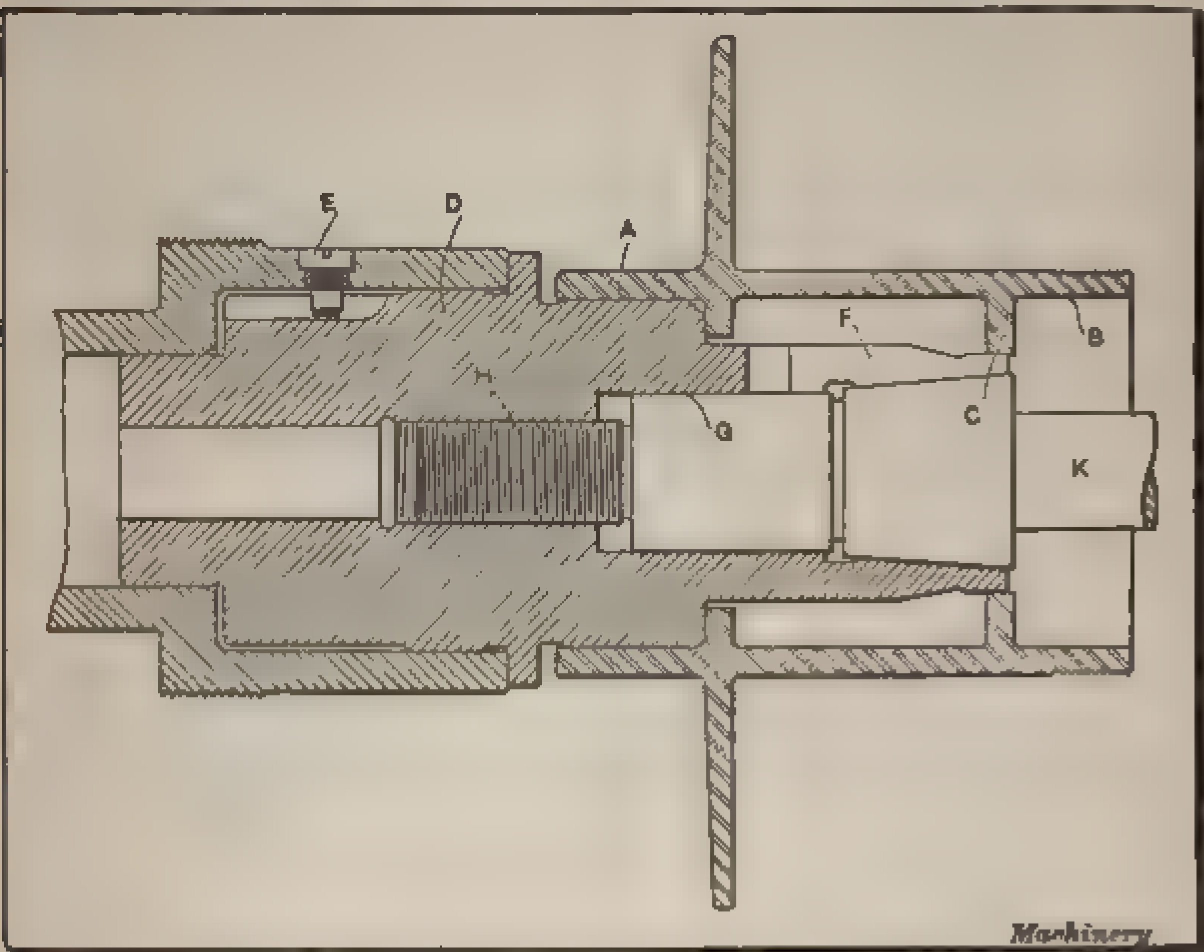

Fig. 6. Arbor with Split Expanding End and Pilot for steadying Tools

the end of the spindle at B. The body itself is of steel and is tapped out at C to receive the operating screw E. As in Fig. 6, the thread is a free fit, while the cylindrical portion D is ground to a snug running fit to insure concentricity. The bushing F is saw-cut in six places, three cuts from one end running nearly through, and the other three in like manner, in order to allow uniform expansion of the bushing. Both the bushing and the operating screw are tapered correspondingly at G. The adapter H slips onto the body of the arbor and is located from shoulder M and secured in place by three screws N. A pin driver L in the adapter relieves the bushing of excessive strain. The larger retainer O (shown in detail) is also handled on this same arbor by using the adapter K. The results obtained with this arbor were perfectly satisfactory.

In Fig. 8 the principles of expansion and contraction are both used in handling steel rifle part *A*. The permissible limits of error on this work were very close, so that extremely careful workmanship was necessary. This operation was the final one on the piece, after it had been machined all over, leaving 0.015 inch at *C* for truing to insure absolute concentricity between surfaces *B* and *C*.

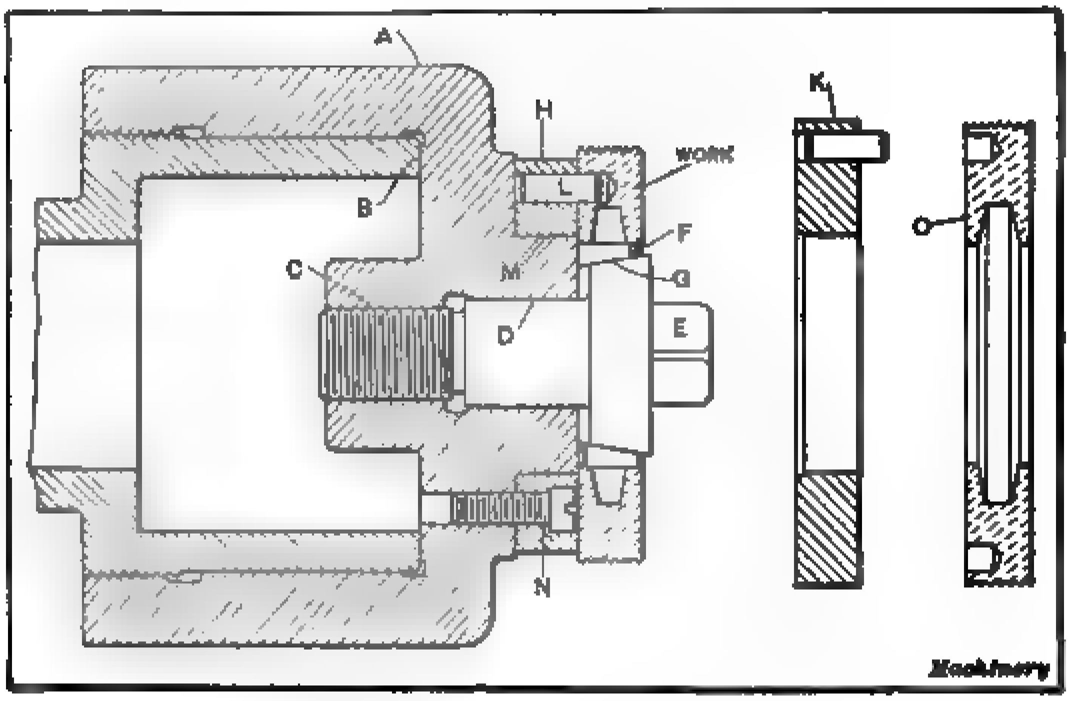

Fig. 7. Arbor having Taper Plug which expands Split Bushing

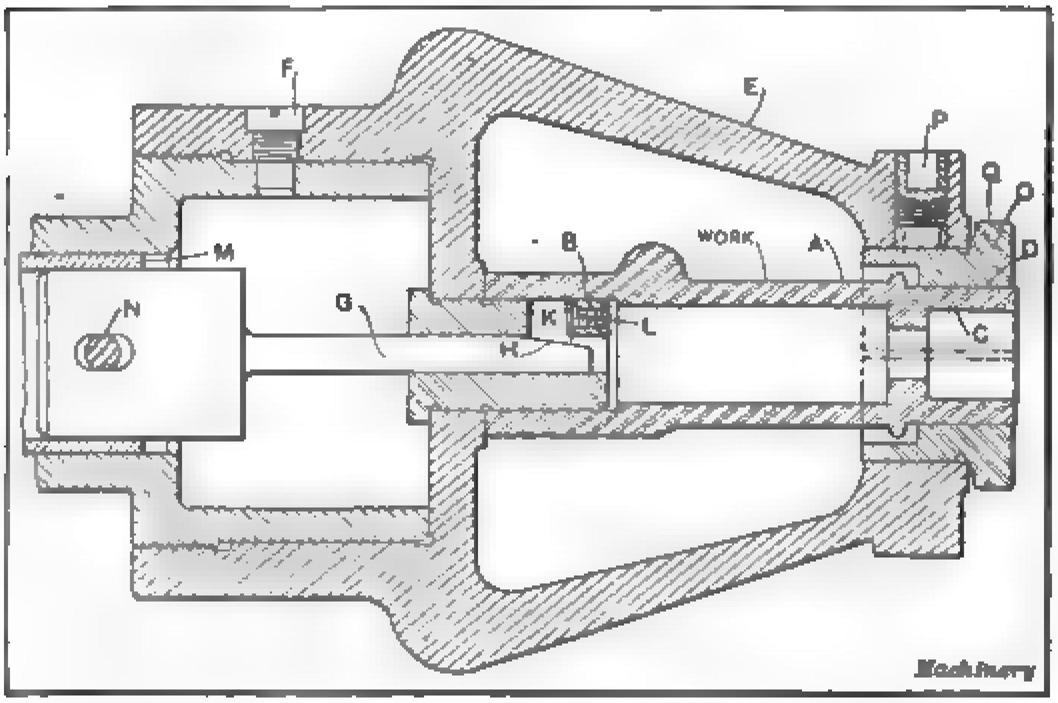

Fig. 8. A Fixture which holds Work by Expansion and Contraction

The machine to which this fixture was applied was equipped with collet mechanism, part of which was used in the operation. The body of the fixture *E* is of cast iron and is screwed onto the spindle nose, being secured against turning by the teat-screw *F*. The sides of the fixture were left open to enable the operator to reach in and grasp the work, in order to guide it onto the locating bushing *B*. The operat-

ing rod *G* was milled at an angle on the forward end *H*, in order to force the pin *K* outward and thus insure rigidity at this point. The collet operating sleeve *M* is secured to the rod by pin *N*, so that the collet closing mechanism can be used to operate the rod. At the forward end of the fixture, the split bushing *O* is used to center the work which is gripped on the finished cylindrical surface *D*. The bushing is knurled at *Q* and is contracted by the action of the hollow set-screw *P*. All important surfaces were ground to an accurate fit and parts subject to wear were hardened. No trouble was experienced with this fixture and the work was machined within the limits of accuracy required.

The steel pinion blank shown at *A* in Fig. 10 has been previously faced at *B* and the taper hole carefully bored, leaving the remainder of the work to be accomplished at the setting shown. The body *C*, in this instance, is of cast iron and is held in position by the tee-screw *D*. The arbor is of tool steel, carefully hardened and ground. The shoe *E* is shaped as shown in the detail above. The operating rod *F* is forced inward by screw *G*, and its release is effected by spring *H* which bears against its inner end. It should be noted that the action of shoe *E* is both outward and backward; therefore it has a tendency to force the work back onto the tapered portion. Obviously key *K* acts as a driver. In order to avoid any chance of springing the arbor out of true a small, special wrench is used for turning screw *G*, so that too much pressure cannot be applied. The nut *L* is threaded on the arbor with a coarse-pitch Acme thread and is of hexagon shape at the forward end. This nut is used to start the work off the arbor when the piece is finished. The stem or arbor *M* enters a bushing in the turret and acts as a support while the beveled surface of the work is being turned. This stem is also used as a pilot for the face mills which form the end of the pinion at *N*. This arbor while used for producing work of the best quality was somewhat fragile and required careful handling.

The pinion blank shown in Fig. 11 has a straight hole instead of a taper one, and the arbor for holding it, while somewhat similar in construction to that shown in Fig. 10, differs as regards a number of points. There are three shoes *C* 120 degrees apart, controlled, as to their outward movement, by the operating rod *I*. These shoes are retained in their positions by [illegible] spring *G*. The bushing *H* on the arbor [illegible] for the work. The various sectional views give a good idea of the construction. This arbor is also of tool steel and all important surfaces are hardened and ground. It gave very satisfactory results, [illegible] construction [illegible] careful handling.

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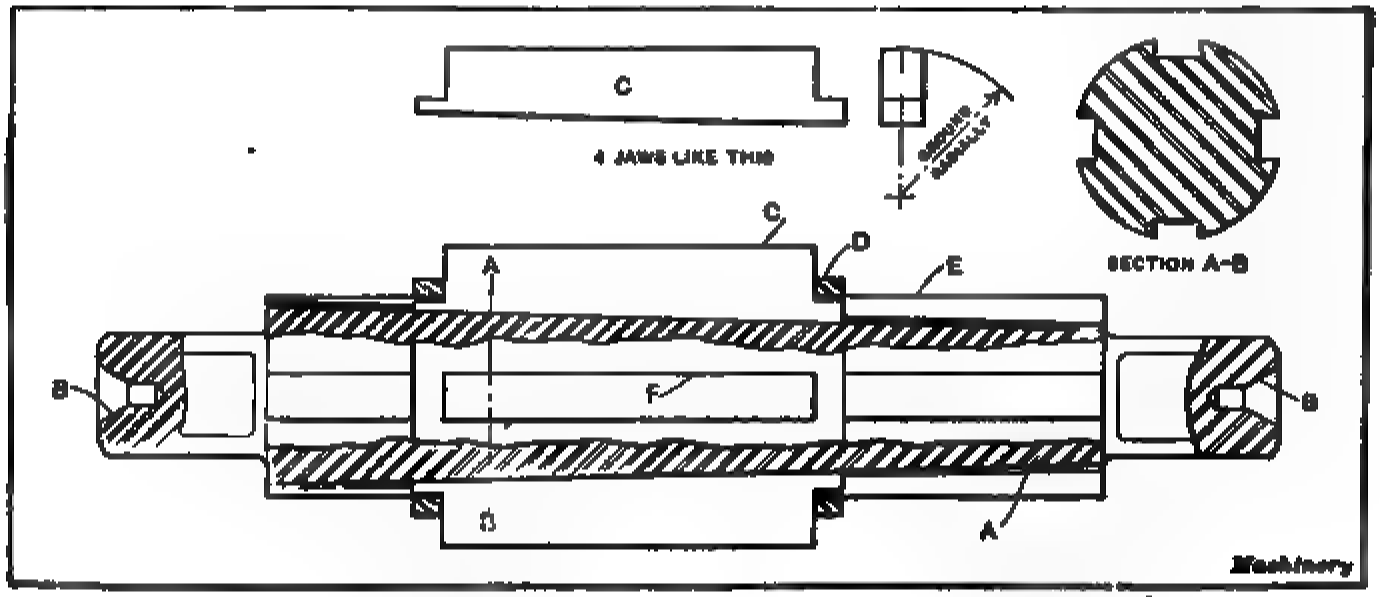

Fig. 9. Expanding Arbor with Sliding Shoes retained in Slotted Sleeve

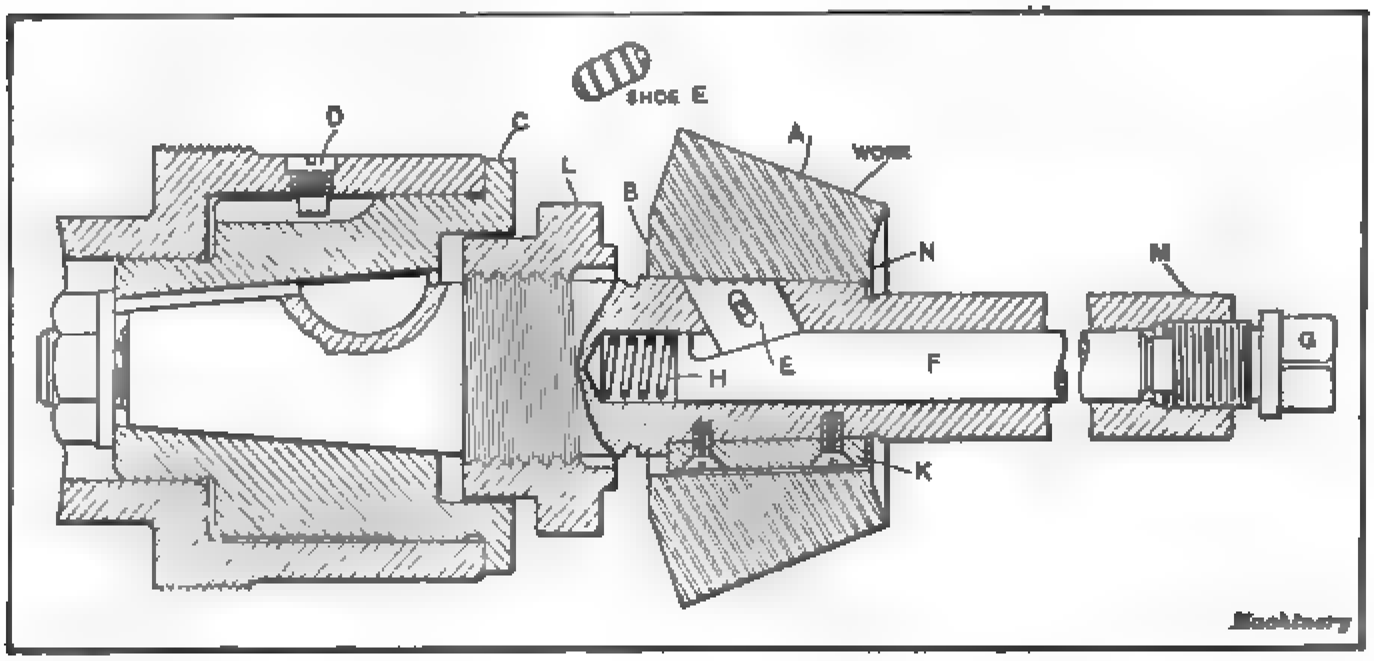

Fig. 10. Arbor having Adjustable Shoe E which bears against Taper Bore of Pinion Blank

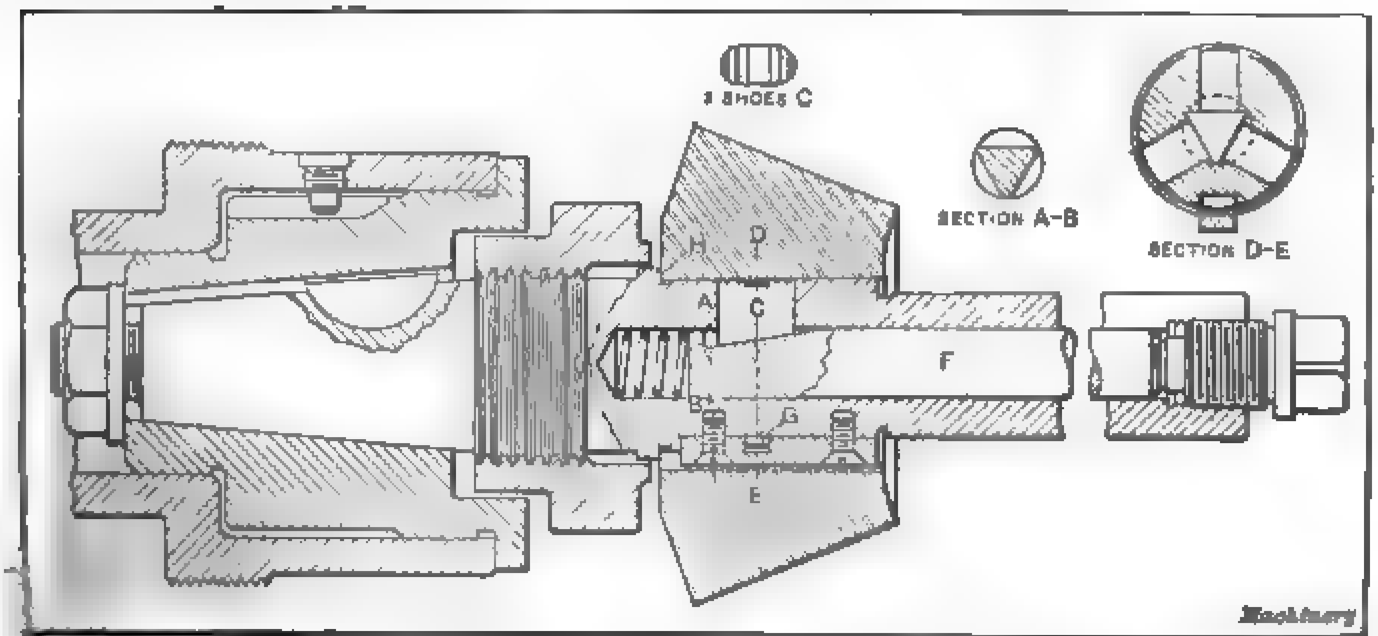

Fig. 11. Arbor for Pinion Blanks, equipped with Three Expanding Shoes

combination locating and holding devices, so that they are more nearly related to locating fixtures in the truest sense of the word It is well to remember that in all fixtures of large size some efficient means of driving the work must be provided, for the thrust of the tool, incident to the cutting action, is much greater on work of large diameter; furthermore, the amount of stock to be removed is usually considerably more than on smaller work. The fixtures themselves

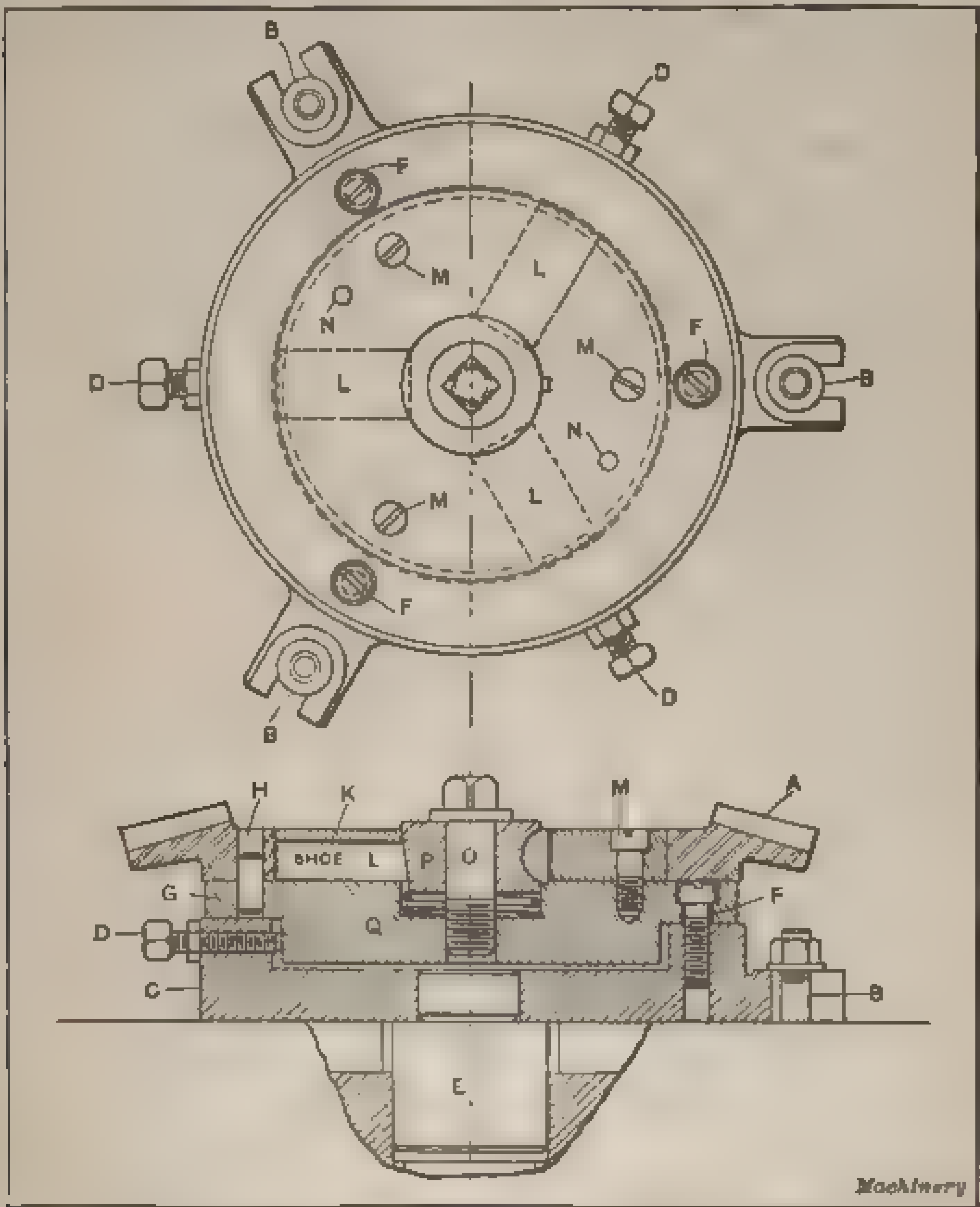

Fig. 12. Vertical Boring Mill Fixture for holding Bevel Gear—The Three Shoes L are forced outward by Plug in Center

should also be of exceptional strength and rigidly secured to the table to prevent movement or breakage.

The large automobile bevel driving gear shown in Fig 12 is of alloy steel, and it has been previously bored and faced on the rear side, the screw holes were also drilled in a jig before placing the gear on the fixture shown. This fixture was rather expensive, being made er of steel (except the base, which is of cast iron), and all work' were hardened and ground or lapped to a perfect fit. Th

located in the center of the table by means of the locating stud *E*, and is securely fastened down by the three T-bolts *B* which enter T-slots in the table. The adjustable part *G* is held onto the base by the three screws *F*. It will be noted that the screw holes have a certain amount of clearance over the body of the screw to permit adjustments to be made. The screws and check-nuts at *D* are for the purpose of con-

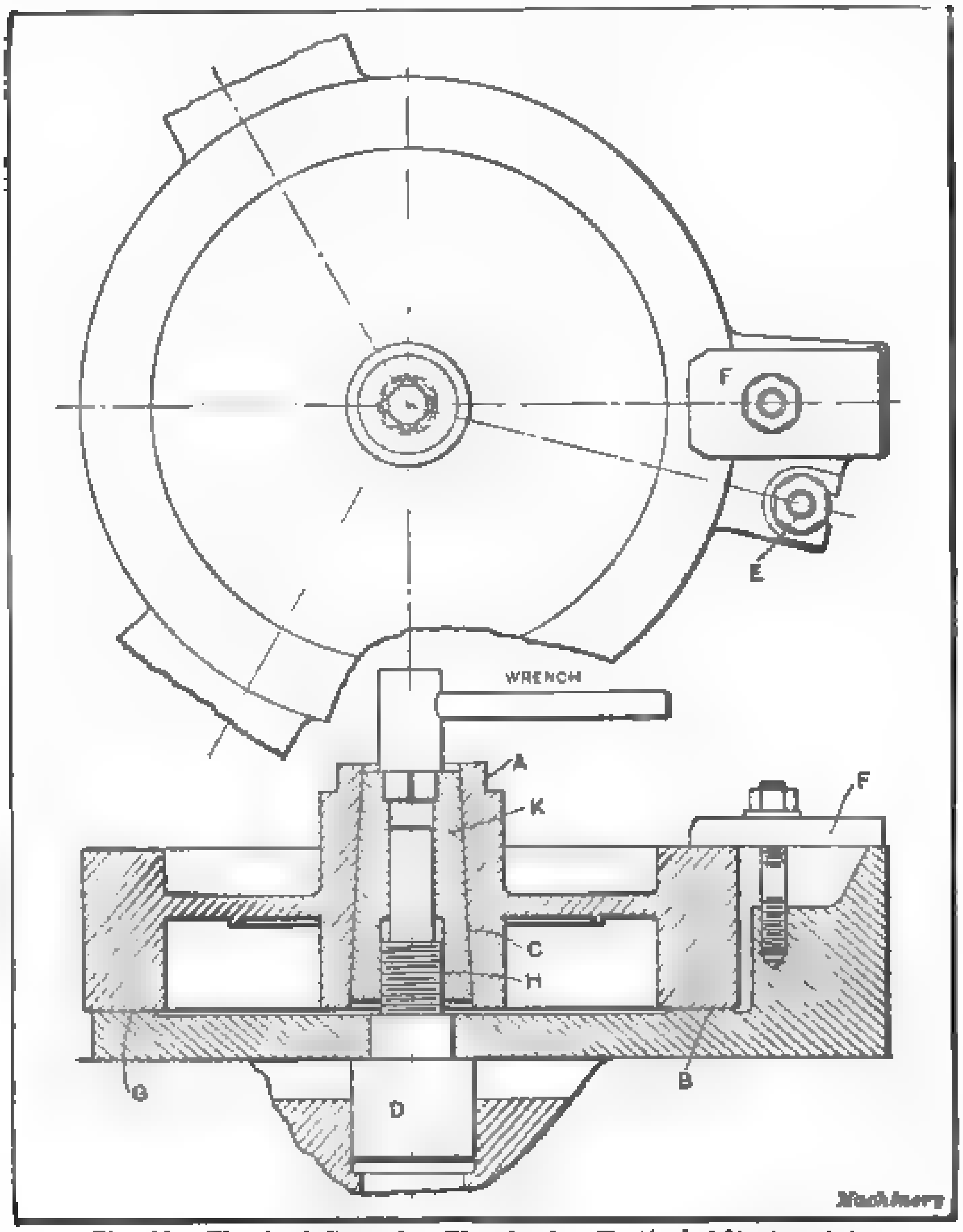

Fig. 12. Flywheel Centering Plug having Vertical Adjustment to compensate for Slight Variation between Bore and Rim Face

veniently adjusting the fixture. A pin-driver *H* engages one of the jig-drilled holes in the work. The upper plate *K* is square slotted at three points *L* to receive the shoes *L*. The screws *M* and the dowels *N* hold this plate in its proper position. The collar-head screw *O* forces down the plunger *P* on which three angular flat spots are milled. These angular surfaces control the action of the shoes *L* and force them out, uniformly, against the work, thus centering it. The spring *Q* simply aids in releasing the shoes.

This fixture is an exceptionally good one, for in its construction every care is taken to insure a true-running arbor and one which can readily be indicated for truth and brought into perfect concentricity by means of the adjusting screws. Its action was satisfactory in every respect.

Fig. 13 shows an automobile flywheel which has a finished taper hole and has been turned, bored and faced in a previous setting. It was essential that the surface *A* should be concentric with the taper hole. As it was practically impossible to machine the face of the flywheel *B* and the taper hole *C* so that they would always come in exactly the same relation to each other, it was necessary to make the taper plug adjustable in a vertical plane. The base of this fixture is of cast iron and is located centrally by means of plug *D* which accurately fits into the hole in the table. The base is clamped in position by three T bolts *E* (see plan view) engaging the table T-slots. Three clamps *F* are used to clamp the work down on the annular rim *G* of the fixture. The plug *D* not only locates the fixture base, but extends above the latter and is threaded at *H*, while above this portion it is cylindrical and is carefully ground to a running fit in the taper bushing *K*. The threaded portion mentioned is a very free fit, so as to permit the cylindrical part to do all the centralizing. In using the fixture, the bushing *K* is screwed down and the flywheel placed in position, after which, by the aid of the wrench, the bushing is raised until it bears in the taper hole. After this, the clamps *F* are swung around and tightened. This is a simple fixture, rather inexpensive, and one which was thoroughly dependable.

Fig. 14 shows a cast-iron double-bevel gear used on harvesting machinery, the gear rings *A* and *B* having cast teeth. These were not machined, thus leaving a rough surface by which to clamp the work, as some support was needed in order to properly machine the annular ring *C*. The cylindrical hole *D* and the end *E* were machined at a previous setting.

The cast-iron base of the fixture is centered by the stud *F* which fits the center hole in the table. This stud extends up through the fixture and is tapered at its upper end to receive the split bushing *G*. This bushing is saw-cut in six places—three from each end—and is shouldered at its upper end so that the vertical movement can be controlled by the operating screw *H*. The collar *K* was pinned in place after the bushing was slipped over the screw. It will be noted that the vertical movement of the bushing is entirely mechanical, no springs being used to effect its release, as in previous instances. The positive locating point of the fixture is at [illegible] necessary to have some support at *B* the four [illegible] ed; these bear against the rough surface of the [illegible] from being pushed down by the screws sh[illegible] hich the screws bear is milled back at [illegible] rim of the gear has four cored holes [illegible] for holding and driving. These are [illegible] In

this connection it is well to note that these hook-bolts are well backed up by a portion of the fixture *N*, for a hook-bolt which is not backed up in some way is worse than useless. This fixture was capable of rapid manipulation and the results obtained by its use were within the necessary limits of accuracy.

An Expanding Arbor for the Vertical Milling Machine

In one of the large automobile factories, considerable trouble was experienced in the manufacture of eccentric piston rings by the break-

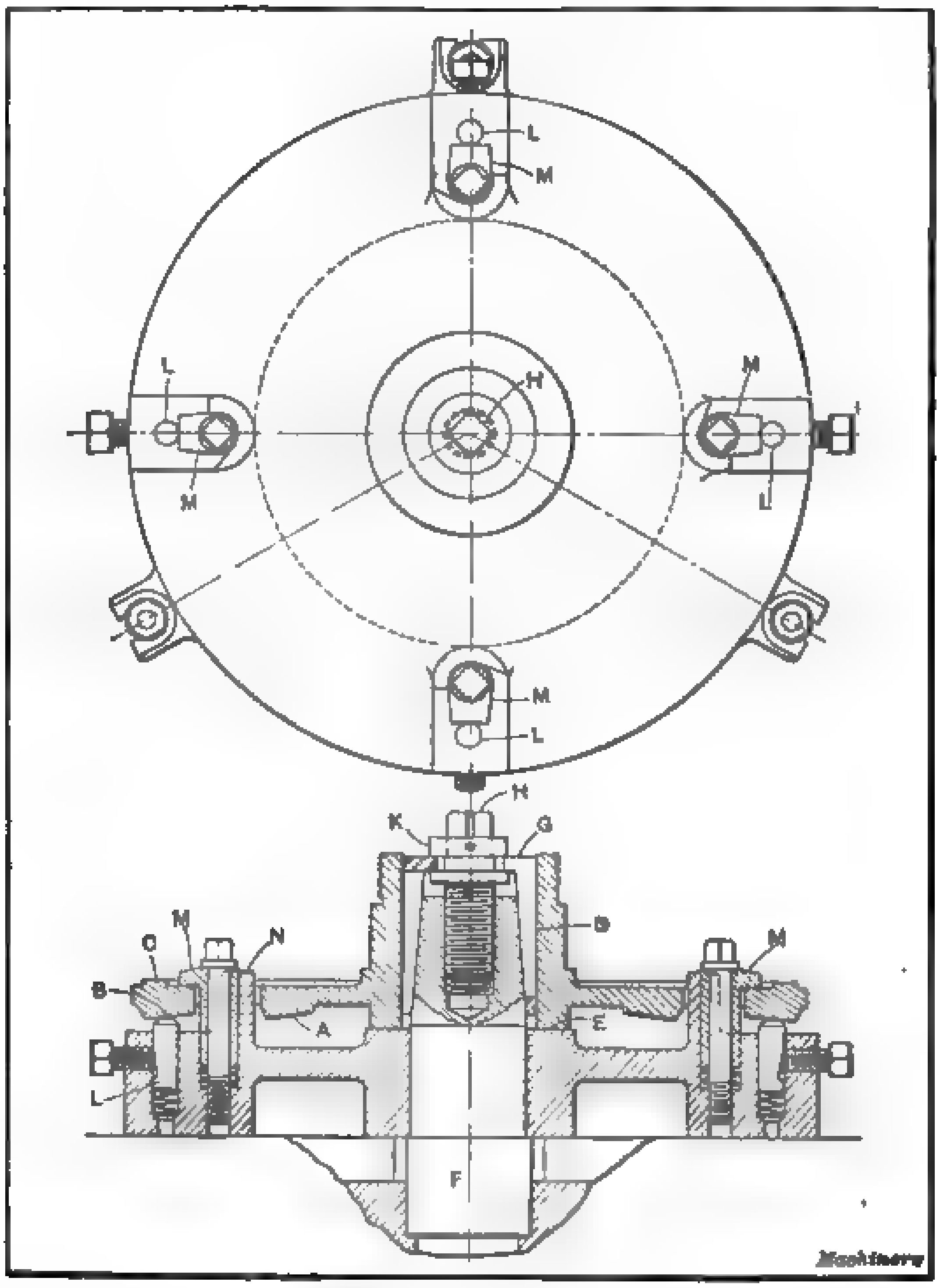

Fig. 14. Vertical Boring Mill Fixture for Special Design of Bevel Gear

ing of the rings as they were being cut off on an automatic machine. A new method was therefore devised by which the "ring pots" were bored and turned eccentric and then taken to a vertical milling machine where they were placed on the arbor shown in Fig. 15. The

fixture of which the arbor forms a part is located in the center of a circular milling table by the stud *B*, and is secured to the table by means of the three screws *A* in the T-slots. The stud is tapered at its upper end to receive the split bushing *D*, and is secured by the pointed screw *C* and prevented from turning by the key *E*. The bushing was saw-cut in six places to permit expansion, and was also counterbored in three places at its lower end to make a pocket for the coil springs *F*. These springs tend to make the releasing of the split bushing easy after the work has been done. The collar *G* bears on the upper

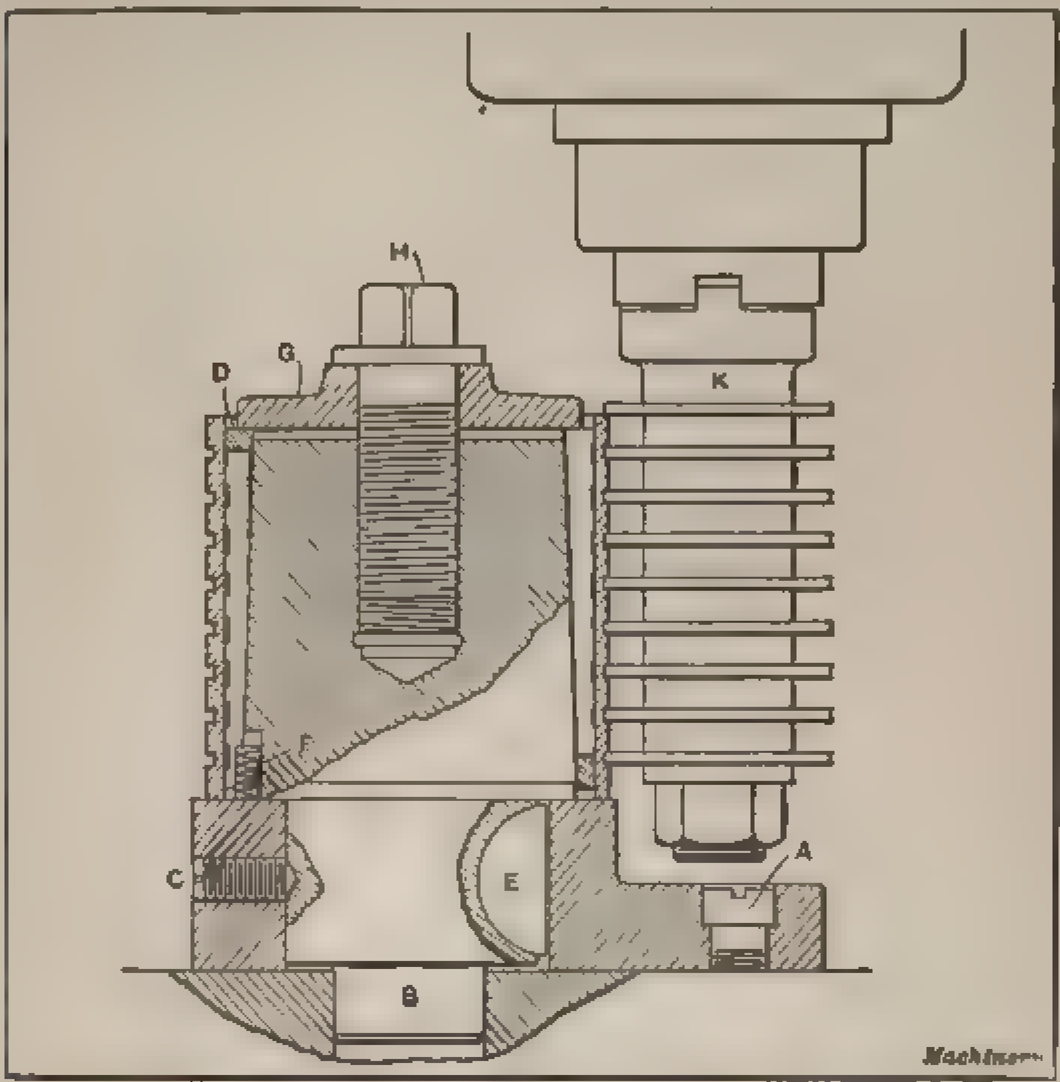

Fig. 15. Expanding Arbor for holding Casting while Gang-sawing Packing Rings

portion of the split bushing *D* and is operated by the screw *H* which is threaded into the body of the arbor.

A special arbor *K* in the spindle of the vertical milling machine was arranged with a gang of saw cutters properly spaced for the correct width of ring. As the table is revolved by power feed, the gang of cutters produce a set of nine clean and unbroken rings. It may be noted that the split bushing is relieved on its periphery at th[illegible] nts where the cutters pass through the work, in order [illegible] cutting edges on the hardened surface. This [illegible] very carefully and proved very satisfactory. To [illegible] knowledge, it is still in use although made ov[illegible]

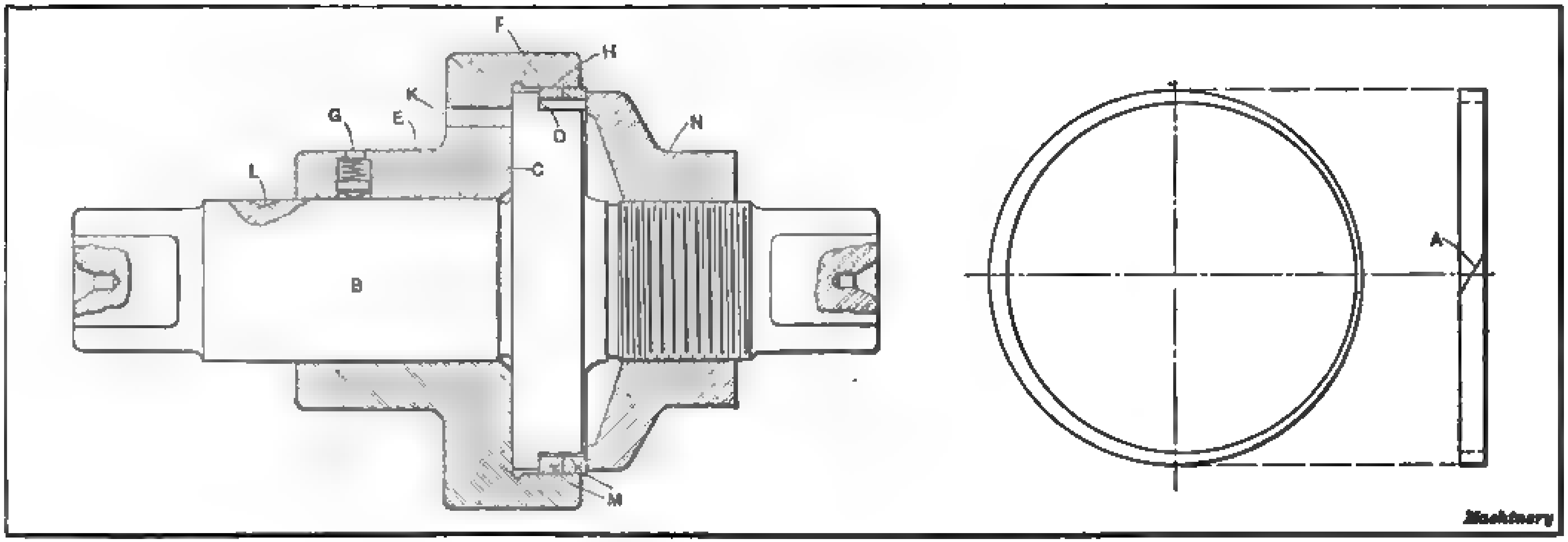

Fig. 16. Arbor for compressing and holding Split Packing Rings while grinding

A Grinding Arbor for Piston Rings

The right-hand view, Fig. 16, shows an eccentric piston ring for a gas engine which has been bored, turned eccentric, ground parallel on the sides and split apart at the point *A*. The arbor shown to the left in the same illustration was used for grinding the periphery to make it perfectly cylindrical after it had been split and closed up at *A*. The body of the arbor *B* is of tool steel with generous centers in each end. These centers were lead-lapped after hardening and before grinding the cylindrical portion. The faces *C* and *D* are also carefully ground. The locating collar *E* is of tool steel, hardened and ground to a very close running fit on the arbor and at the point *H* where the rings fit. The portion *F* is knurled to give a good gripping surface for the hand when pulling back the sleeve. The spring detent *G* serves to hold the sleeve in position when it is pulled back out of the way for grinding. The hole *K* is an air hole and is very essential, for as the parts are all very closely fitted the

suction is so great that it is almost impossible to pull back the sleeve unless this relief hole is drilled A longitudinal groove along the arbor would answer the same purpose, but is more likely to catch dirt and thus cause trouble The nut *N* is of tool steel, has a coarse pitch thread and is made hexagon at the small end. The faces which bear against the rings are ground parallel with the thread. When in use, the nut is slipped back out of the way and the two rings *M* are sprung into place inside the locating collar after which the nut *N* is brought up against the rings and tightened. The locating collar is then pushed back out of the way, until the detent snaps into place, and the work is then ready for the grinding operation on the periphery. Arbors of this type are in daily use in nearly all of the automobile factories in this country

The various types of arbors and fixtures illustrated and described in this article cover representative work of nearly all kinds, and may be modified to suit almost all possible conditions whether they affect the work part, the machine, or both.

CHAPTER III

WORK-HOLDING ARBORS AND METHODS FOR TURNING OPERATIONS

The developments in the design of machine tools during the last ten or fifteen years have brought these machines to a high degree of perfection. Many are provided with features which make great precision possible, and a workman who understands how to get the most out of one of these modern machine tools can produce very accurate work. It should be remembered, however, that no matter how accurate and how well adapted to rapid production the machine may be, if the methods of holding the work are not equally well thought out there is comparatively little gained As a matter of fact, this point is neglected in a great many machine shops In a few instances, we find planning departments and efficient tool-designing departments where the methods and appliances to be used in manufacturing are carefully considered In the majority of shops, however, the workmen, or at least the foremen, are left to devise for themselves the methods by which the work is to be held in the machines. In the few cases where the workman is unusually ingenious, this may be of advantage, but it is seldom possible for the man at the machine to consider both the accuracy required and the rapidity of production with anything like the care that can be done by a designer especially detailed to do this work

Therefore, it is becoming generally recognized that in order to take advantage of the full capacity and adaptability of modern ma-

chine tools, it is necessary that the work-holding and machining methods be worked out by designers of equal ability to those who actually design the machine. In the following a few methods will be shown for holding different classes of work for turning and facing operations in the lathe. The arbors and devices shown were designed at the Jones & Lamson Machine Co., Springfield, Vt., for use in the Fay automatic lathe; but as far as the methods for holding the work are concerned, they may be employed with equal advantage in any engine lathe, and are therefore capable of wide application. The tooling arrangements shown in each case are, of course, especially adapted to

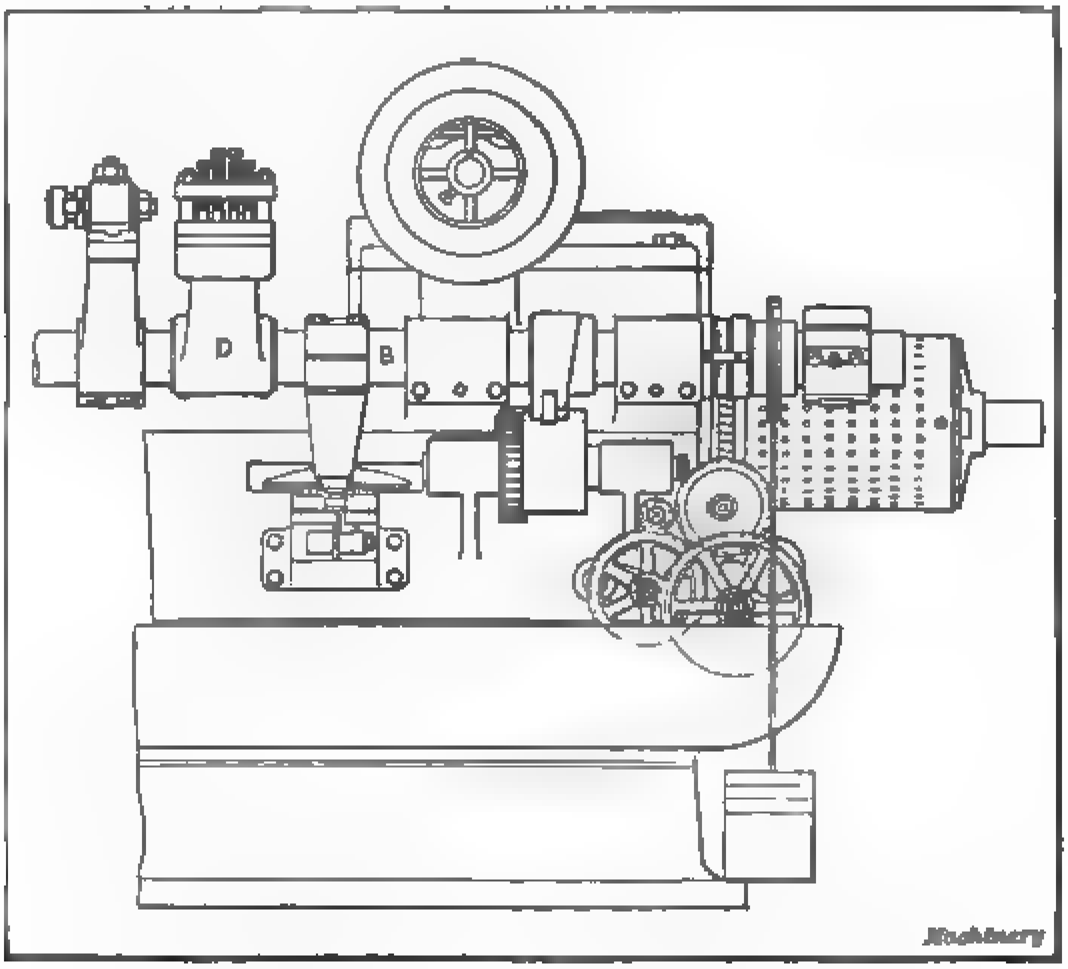

Fig. 1. Rear View of Head End of Fay Automatic Lathe

the Fay automatic lathe with its front and rear tool-holders, but by means of a special tool-block many engine lathes could be rigged up to perform the work in a similar manner. These tooling arrangements will probably suggest other machining methods.

Principles of Arrangement of the Fay Automatic Lathe

In order to make the following article intelligible in so far as the arrangement of the tools is concerned, it will be necessary to refer briefly to the construction of the Fay automatic lathe. The line engraving Fig 1 shows a rear view of the head end of the machine. Fig. 2 shows a sectional view The main or work-spindle is driven by worm gearing from a cone pulley mounted at right angles to it. A series of cams is provided for controlling the cutting tools, and by means of a clutch mechanism operated by adjustable dogs, the cam-

shaft may be given a slow feeding movement or a rapid idle movement over any portion of the periphery of the cam. Two heavy bars, *A* and *B*, extend the full length of the machine and on these the various carriages and tool-holders are mounted. Each of these bars is controlled by a cam both as regards the longitudinal and the rocking movement about their axes. The rocking movement of the front tool-holder *C* is caused by templets or cam surfaces on the slide or former bar at the front of the bed on which the outer end of the carriage rests. These templets may be given any desired shape which will be copied by the tool as the carriage is fed longitudinally. The carriage may also be held stationary and the former bar carrying the templet may be fed to the right or left, thereby causing the tool to feed directly in or out at right angles to the axis of the work. The main tool bar is operated longitudinally by an internal cam surface within the cam drum shown to the right in Fig. 1, and the tool slide at the rear is rocked by a cam beneath the headstock. It will be understood from this description that the front tool-block *C* is especially adapted to straight turning, taper turning and forming operations while the rear tool holder *D* is intended for operations requiring the tool to be fed in toward the center of the work after which, of course, the tool-bar can be fed longitudinally for ordinary straight turning operations.

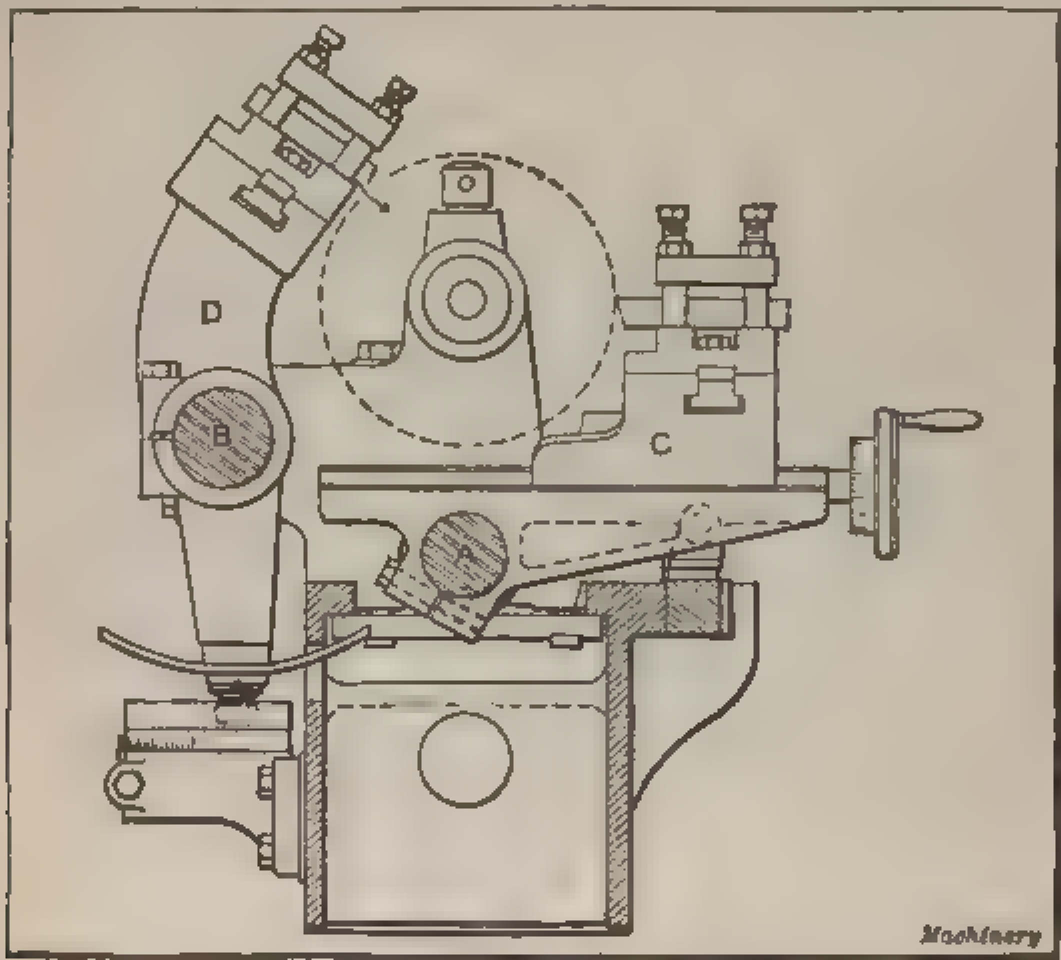

Fig. 2. Cross-sectional View of Fay Automatic Lathe

Arbors for Holding Bushings made in Halves

The arbor shown in Fig. 3 is used for holding the type of half-bushings illustrated while turning the outside. When performing this operation, it is necessary that the bushings be so held that the parting line comes exactly in the center, so that the two halves are interchangeable. At the same time, they must be held so that the outside will be true with the inside, which has already been finished by a formed convex milling cutter. When the inside has been finished, the two halves are clamped to an arbor and the ends are finished to a beveled surface by a hollow mill. The half-bushings are then ready to be placed on the arbor shown in Figs. 3 and 5, where they are held in place by beveled collars slightly corrugated on the tapered surfaces to form an effective drive. By holding the bushings in this manner

Fig. 3. Half bushings to be machined and Arbor used for holding them while turning Outside

the whole of the outside can be finished at one setting. The rear tool-block carries the roughing tools and is first fed inward in the direction of arrow *A*, Fig. 5, and then to the left in the direction of arrow *B*. The roughing cut is divided between the tools *C*, *D*, *N* and *O*, so that the tool slide needs to feed from *E* to *F* only in order to complete the roughing cut. The tool *N* roughs out the top of the shoulder on the bushing, while the tool *O* roughs out the part of the bushing to the right of the shoulder.

The finishing tools are held in the front tool holder. Tool *H* is first fed in the direction of arrow *G*, finishing one end of the bushing, and then tool *K* is fed in the direction of arrow *L* to finish the other end of the bushing, at the same time, tool *M* finishes the collar or shoulder shown. The roughing is entirely completed before the finishing cut begins. The finishing cut on the long surface to the left on the bushing is done by one tool *K* and not by two tools as in the case of the roughing cut, because if two tools were used for finishing it would be

difficult to avoid a slight mark on the turned surface at the point where the two cuts meet. Fig. 4 shows the work and tools as arranged in the machine.

In Fig. 6 is shown an arbor used for holding a tapered bushing while finishing the outside; the bushing is shown in Fig. 7, and Fig. 8 shows the work and tools sets up in the machine. In this case the hole in the bushing, which is made in halves as in the preceding case, is rough. The joint between the two halves must, however, come exactly in the center of the finished bushing so that the two halves may be interchangeable. The first operation is to plane the joints; then the two halves are clamped together and the ends are finished by a hollow mill to form a bevel bearing for the clamping collars of the arbor. When milling the ends, the joint must be held central in

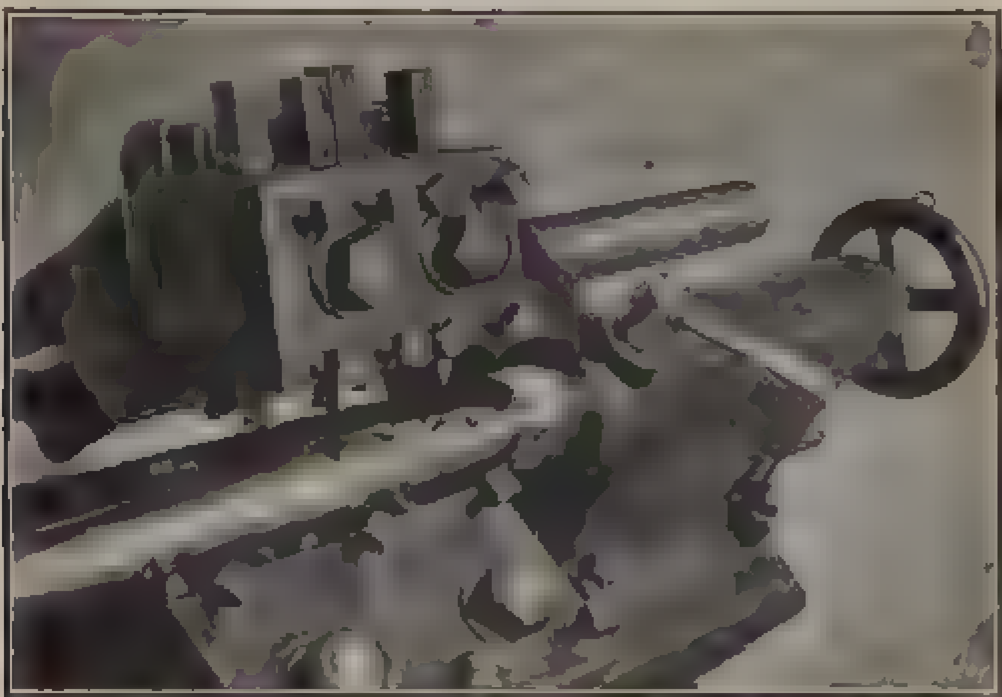

Fig. 4. Tools illustrated in Detail in Figs. 3 and 5 set up on Fay Automatic Lathe

a jig especially designed for the purpose. The half-bushing is then clamped on the arbor shown in Fig. 7, the beveled surfaces of the collar and shoulder holding it true. Fig. 6 shows the arrangement of the roughing tools, the arrows indicating the direction in which they are fed. The front and rear tools are in action simultaneously. The front tools are guided by a taper former on the former bar. In the roughing operation the small surface at *A* will, of course, be turned on a taper, but this will be corrected by the finishing operation, the tooling arrangement for which is shown in Fig. 9. In this case the tools in the back tool-holder finish the short taper on the shoulder and the top of the projection. The long taper surface of the bushing is finished by the tool held in the front tool-holder. Arrangements are made for relieving the tool on the ret[illegible]

Fig. 10 shows another tapered [illegible] es, which is turned on the outside before t[illegible] re the ends are not finished because othe[illegible] the

work so as to locate the joint in the center of the finished bushing. There are lugs on the inside of one of the half-bushings, which bear against shoulders on the arbor, as shown by the section to the left. After the two halves are finished by planing, the half provided with the lugs is first placed on the arbor so that the lugs bear against these

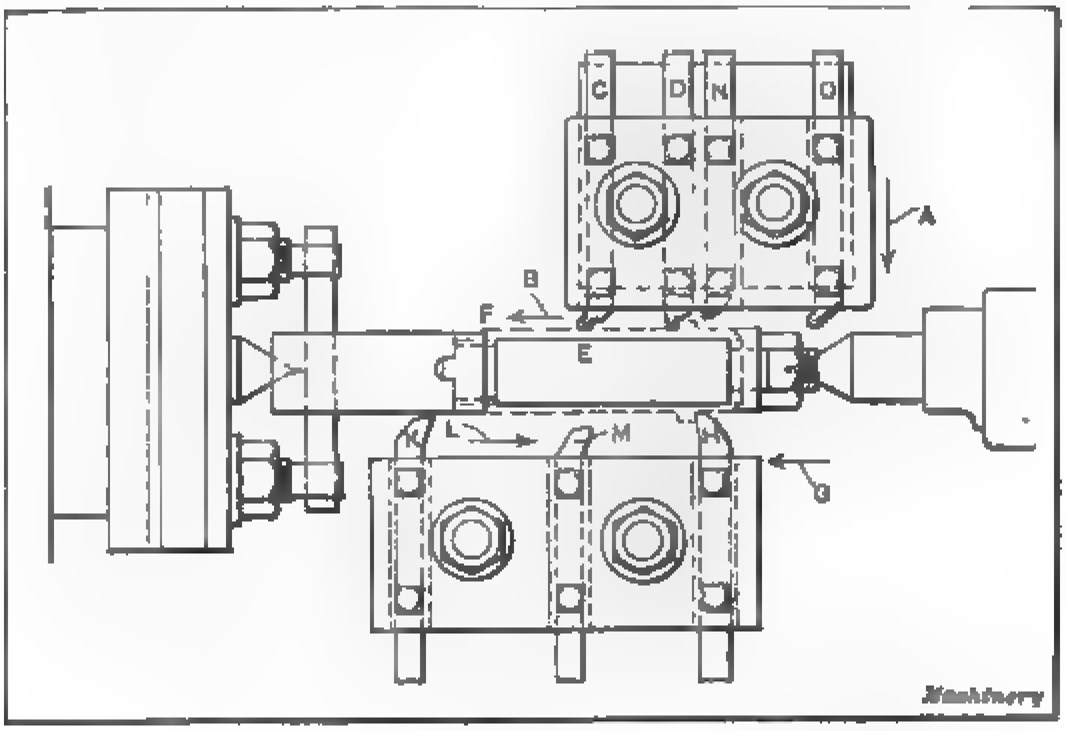

Fig. 5. Tool Arrangement for turning Half-bushings shown in Fig. 3

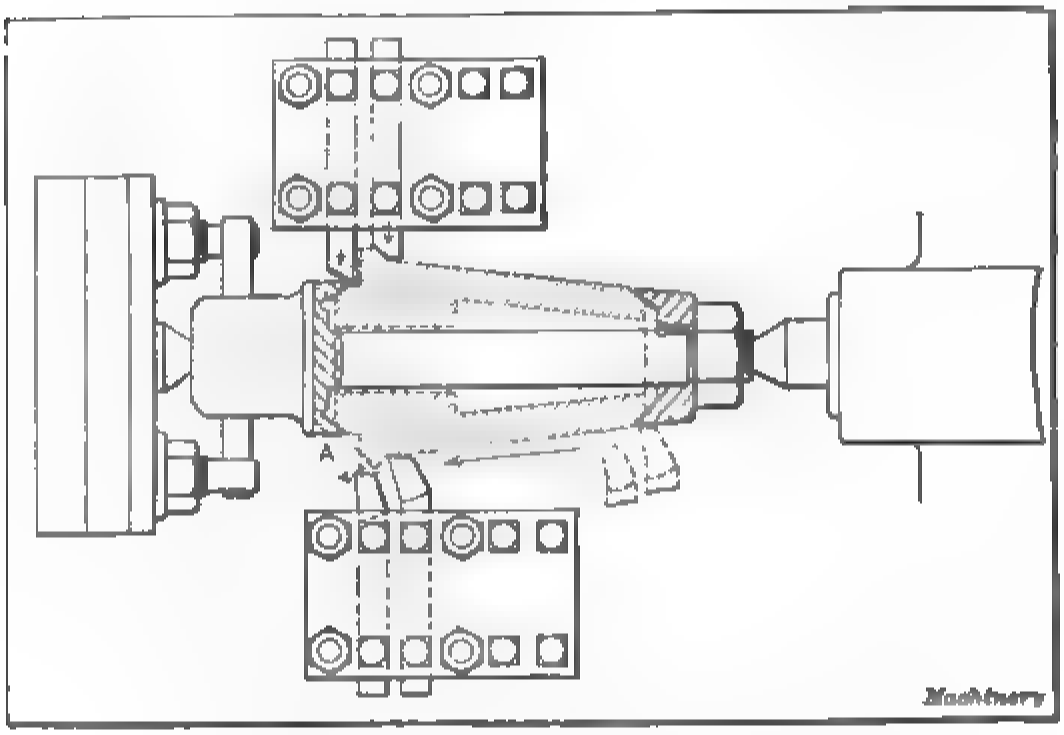

Fig. 6. Method of holding Tapered Bushings shown in Fig. 7

shoulders, which insures a correct location. As the ends are rough, the clamping arrangements must be made to take care of any adjustment necessary to provide a full bearing. A bushing *C* is therefore provided within which slide two half-bushings *D*, operated by adjusting screws. By means of these screws each half of the bushing to be turned can be clamped tightly against the collar at the other end of

the arbor; at the same time the joint in the center will be held in correct relation to the center of the arbor. The roughing cut is divided between the two tools in the rear tool-holder and the finishing is done by the tool in the front tool-holder. Only the short surface from E to F is finished.

Fig. 7. Arbor for turning Tapered Bushings and Work for which it was designed

Fig. 8. Tools shown in Detail in Figs. 6 and 7 set up on Fay Automatic Lathe

Holding Work with Square Holes

A piece of work with a square broached hole by which the piece is held on a square arbor is shown in Fig. 11. In this case the cutting is all done in one direction so that it is unnecessary to provide for clamping the work for endwise motion. An illustration of the piece

ork and the arbor, also showing the work in place on the arbor, iven in Fig. 12. The tools, as inserted in their respective holders, shown in place on the machine in Fig. 14.

'ig. 13 shows a simple method for holding a gear blank with a lare hole. The hole in the blank is first bored, after which the

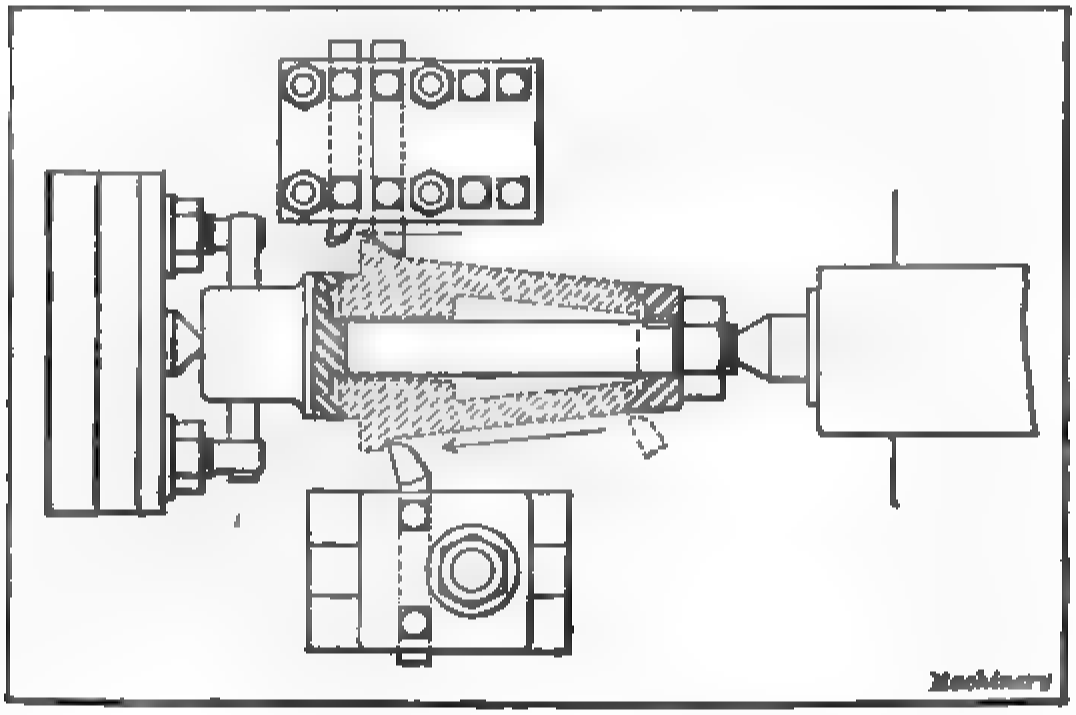

Fig. 9. Finishing Tool Arrangement for Bushings shown in Fig. 7

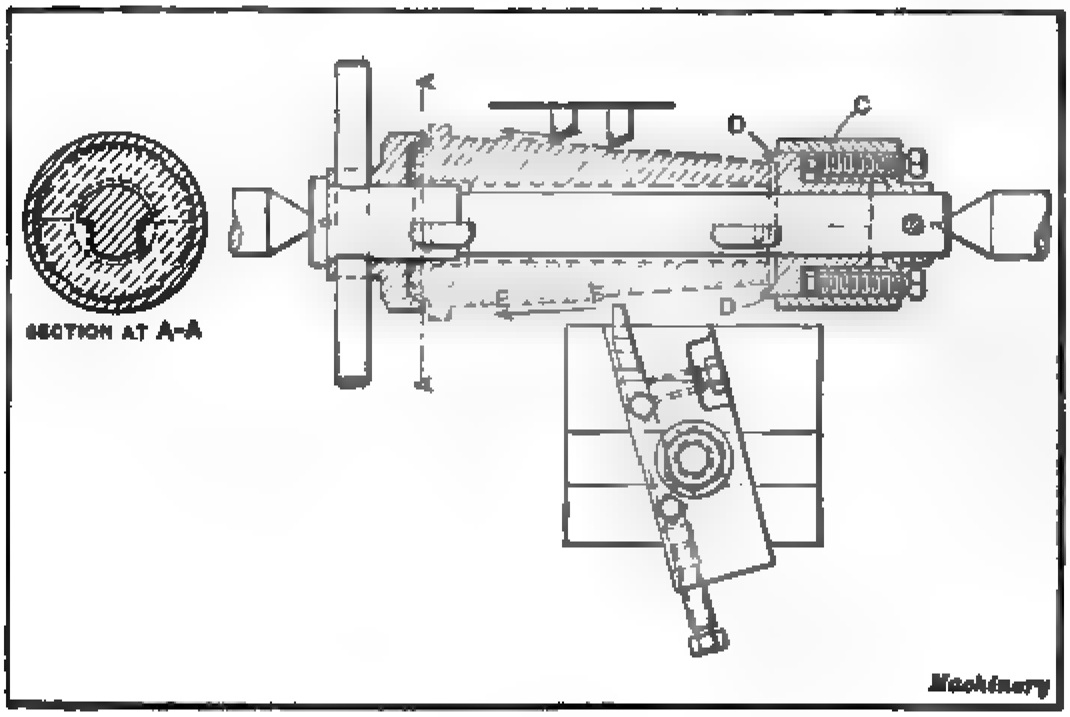

Fig. 10. Arbor for holding Tapered Bushings with Rough Ends

piece is roughed all over except on the large diameter and on face next to it, as it is held by these surfaces in the turret lathe. ' the hole is broached, two keyways being provided at the same after which the piece is placed on the arbor, the keys being ¢ ' -ht enough to hold it in place. The tooling arrangemen -- is shown in the illustration

When a piece of work is to be finished on the Fay automatic lathe, or in any lathe with multiple tools and fixed stops, it is necessary that the endwise location of the work be always the same; hence when

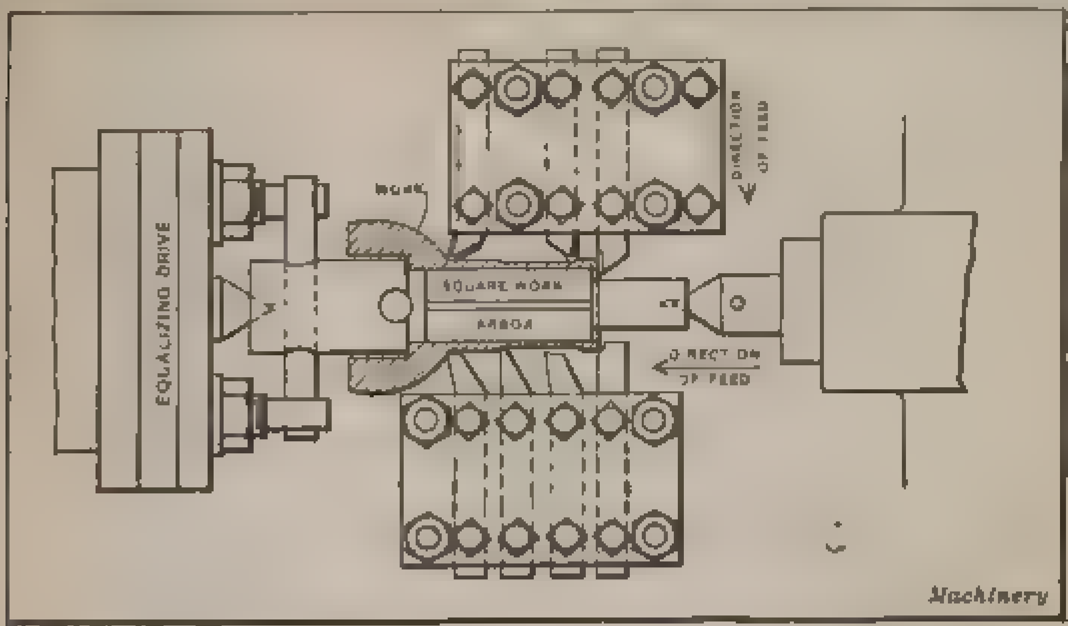

Fig. 11. Turning Work carried on Arbor passing through Square Broached Hole

work with a round hole is to be finished, it cannot be held on an ordinary arbor with a slight taper unless the hole is so accurately finished that the piece will come to a driving fit at a given place on

Fig. 12 Square Arbor for carrying Work with a Square Broached Hole

the arbor, in which case the point to which the work is to be driven may be determined by means of a simple gage which acts as a stop. As a matter of fact, some firms make it a point to machine the holes in work of this kind so accurately that the work can be driven onto

an arbor and come to a driving fit at a given point. This can almost always be done with bronze bushings, as there is enough elasticity in this material to permit the pieces to be forced down to a certain position. With this method of holding, both ends of the work can be faced, as there are no clamping arrangements to obstruct the path of the tools.

Holding Work by means of Expanding Bushings

One of the simplest methods for holding work with a finished hole is by means of expanding bushings. This method makes it possible to chuck the hole in a drill press and still hold it at a given position on an arbor without obstructing the ends of the work, and in such a way that both ends of the work can be faced. In the case shown in Fig. 15 the hole was too long to fit a split bushing the entire length, as the thickness of the bushing would have been rather excessive at one end, or else the taper would have had to be made too small; therefore part of the arbor is turned straight and fits the hole in the gear blank to be turned. In order to insure that the piece be placed in the same position longitudinally each time, a gage bushing, an end view of which is shown in the lower left-hand corner of the illustration, is used to gage distance *A*. The piece of work is dropped onto the arbor and secured loosely against the gage; then the gage is withdrawn and the nut is tightened to hold the work firmly in place. The arrangement of the tools for finishing this piece is clearly indicated in the illustration.

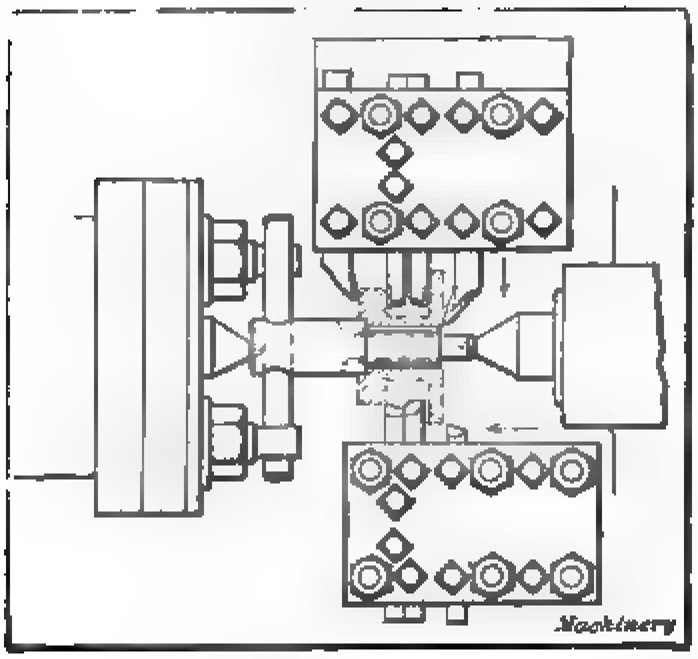

Fig. 15. Gear Blank held on a Square Arbor

In Fig. 16 is shown another example of an arbor for clamping work by means of a split bushing. The work here shown is an armature bearing box. No gage is necessary in this case, as the work is located by a shoulder at one end of the arbor, only one end of the work being faced off. The roughing is done by the tools in the rear tool-holder and the finishing by the tools in the front holder. Another interesting method of holding work while machining is shown in Fig. 17. The work here shown in position on the arbor is a shrapnel shell. The work is threaded on the inside at one end and can thus be screwed onto a threaded portion of the arbor. The end of the arbor is split and provided with an expander. The rear tool slide holds the roughing tool which faces the end, and also a forming tool which comes into a surface free from scale that has been roughed off by one of the

tools in the front slide The direction of the cut of the tools in the front slide, first inward, then parallel, and then slightly outward, is shown by the arrow Fig. 18 shows the arrangement of the tools for roughing and finishing the tapered end of the shell and for knurling a groove at the closed end. In this case a special grooved former must be used in place of the taper attachment of the machine at the rear When the front tool at the left has completed its cut the finish-

Fig. 14. Turning Work carried on a Square Arbor in a Fay Automatic Lathe

ing tool-holder drops in, permitting the tool to the right to perform the knurling operation. In this case a former is clamped to the former bar of the machine.

Supporting Thin Work from the Inside

The most interesting holders for work that is to be machined in the lathe are, perhaps, those that are arranged to support thin work from the inside In Fig 19 is shown one example of a piston held by an equalizing arrangement. This arrangen ... able only to pistons which are not to be ground T ... to bore a

hole for a short distance inward at the end of the piston and then drill the wrist-pin hole. The bored portion is used for locating the work in position by means of a stud through the wrist-pin. The method shown in the present illustration, however, permits the work

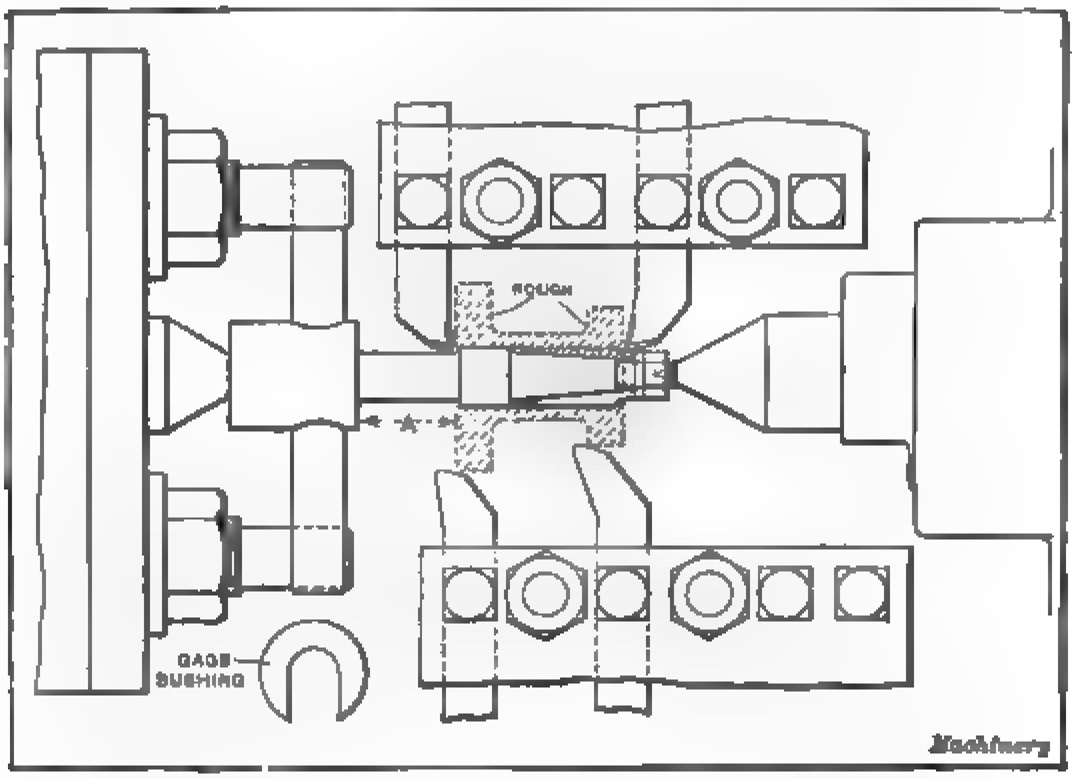

Fig. 15. Example of Work held on Expanding Bushing

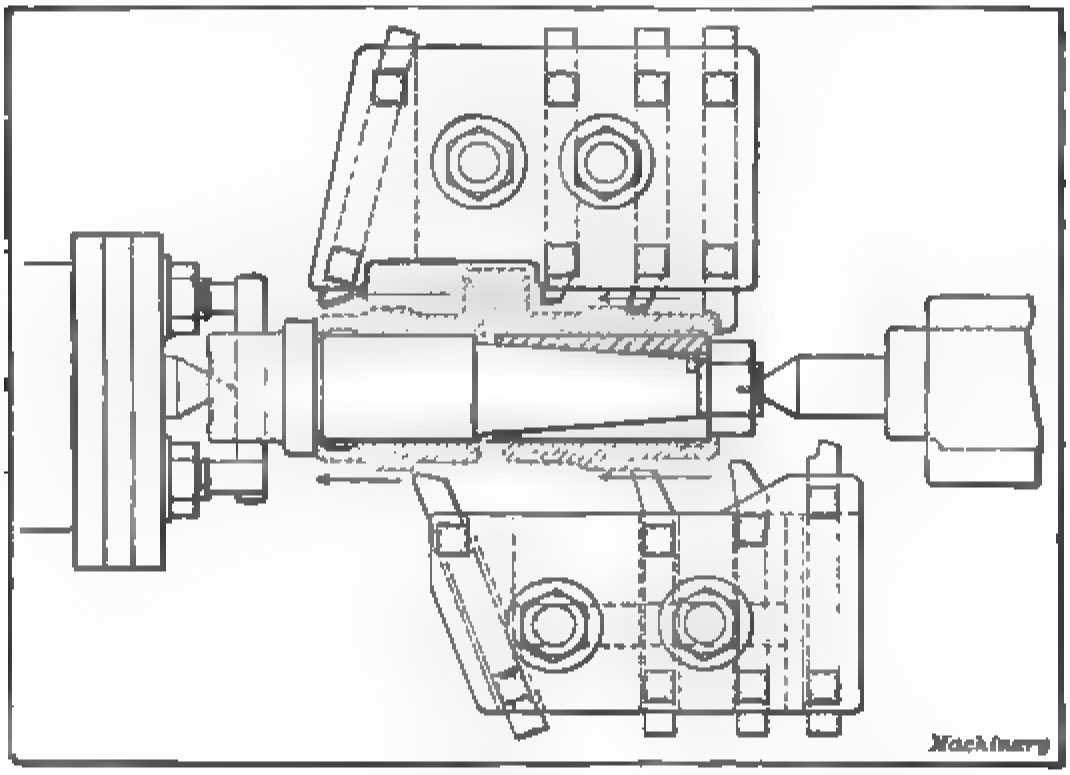

Fig. 16. Another Method of clamping Work on Expanding Bushing

to be done in one operation without any counterboring, and with the assurance of an even thickness of metal all around the piston. One end of the piston is centered in a centering machine If the piston is heavy it may be held by the outside during this operation. If the metal is thin, it is preferable to center it with reference to the inside,

holding the work in a jig like the fixture used in the machine. The holding device consists of three plungers *A* at each end of the piston, which slide in slots cut in the head of bolt *B* and in collar *C*, and which thus both center the work and support it on the inside. In the case of small pistons only two plungers are used at the closed end,

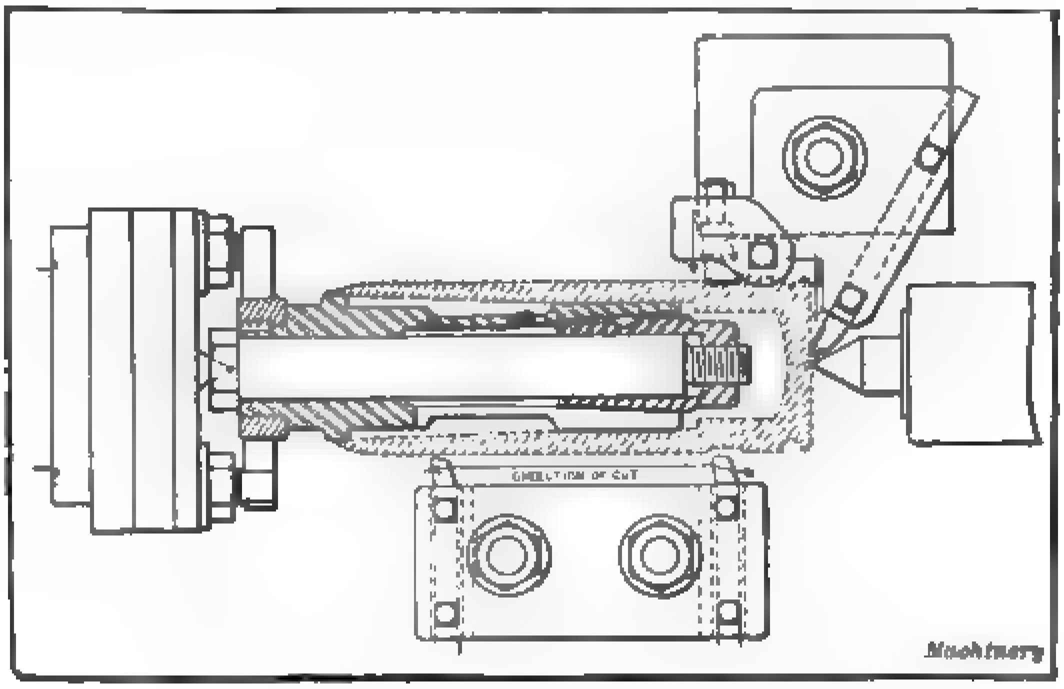

Fig. 17. Combination Threaded and Expanding Arbor for holding Shrapnel Shell in Lathe

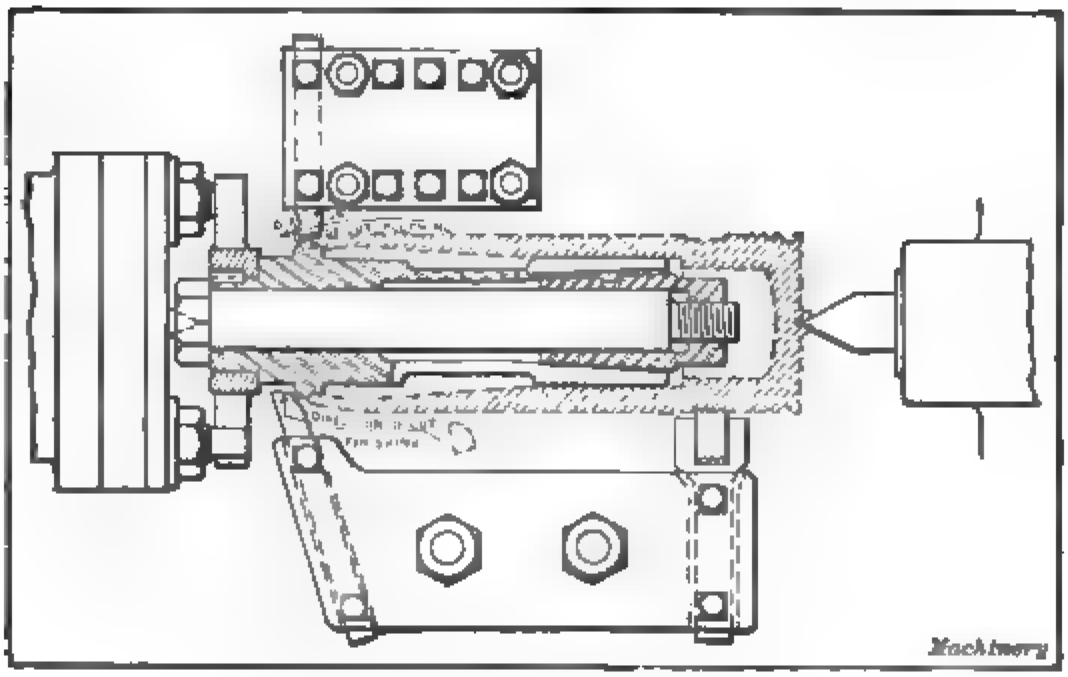

Fig. 18. Tool Arrangement for turning Shrapnel Shell Point and knurling Groove at Closed End

because there is not enough room for three on account of the bosses for the wrist-pin. The bolt with the tapered slot is tightened by means of a nut having a slot in it, which can be reached from the end of the arbor when the fixture is taken out of the machine, by means special screwdriver. The tooling arrangement shown in the tion is that provided for roughing the piston. The two tools

front holder divide the roughing cut between them so that the feed motion needs to be only one-half of the length of the piston.

Fig. 20 shows a method used for supporting the overhanging rim of a long pulley. In this case the pulley is centered by the hole which fits the arbor, and the support must simply act as an equalizer. As will be seen, two floating collars *A* and *B* are provided which are tapered on one side. This tapered side bears against pins *C* and *D*. As the collars are perfectly free to locate themselves with relation to the arbor, it is evident that the pressure on the pins (of which there are three for each collar) will be the same, and there will be no tendency

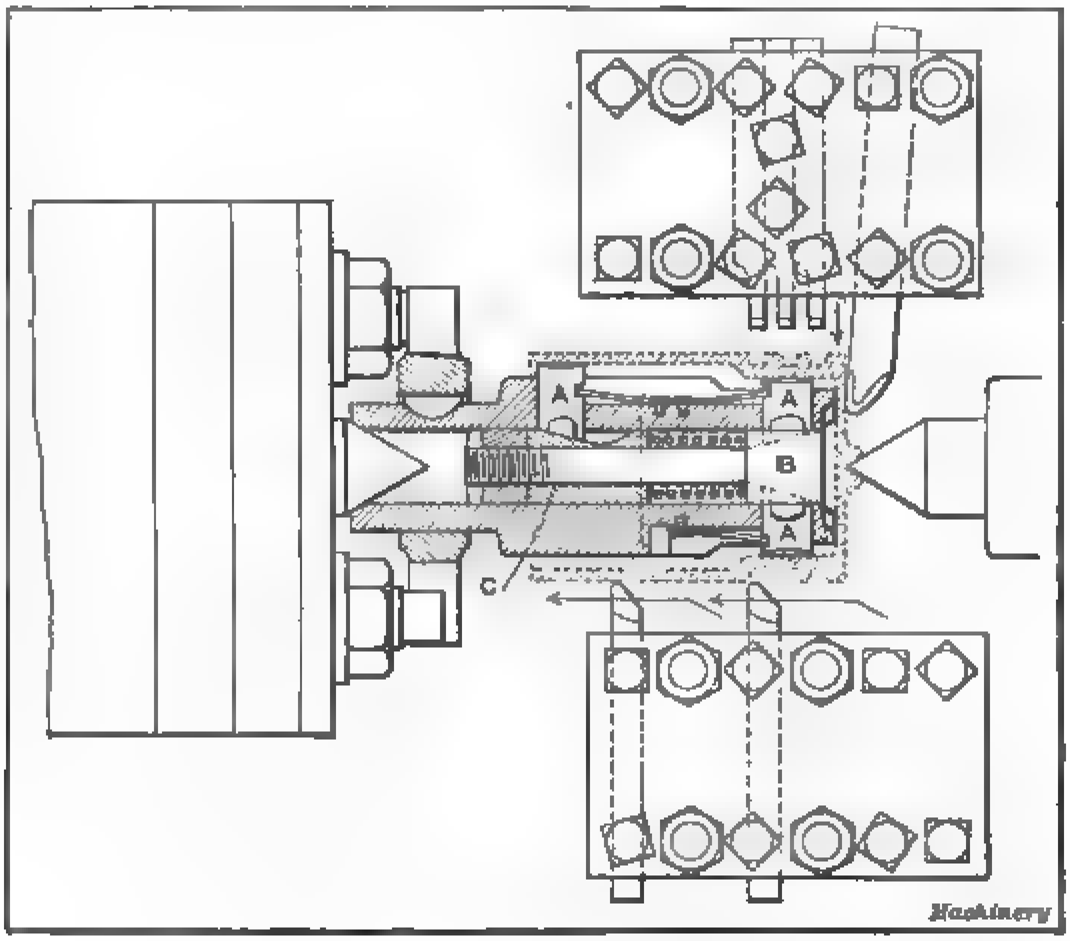

Fig. 19. Arbor for holding Pistons to be turned

to throw the work out of center, but to merely support it with equal pressure at the six bearing points.

Holders for Two Pieces of Work

In many instances it is possible to hold two pieces on the same arbor, thus practically cutting the time of machining in half. The simplest illustration of this is probably that shown in Fig. 21, where two gear blanks, which have been faced on one side and have had the holes bored, are clamped together and faced on the other side and turned on the outside. The arrangement of the tools is of interest; the arrows shown give the direction of the feed and indicate the method of procedure. Fig. 22 shows another case where two pieces held on the same arbor are machined at the same time. A spacer is provided between the two pieces so as to locate the one to the right in

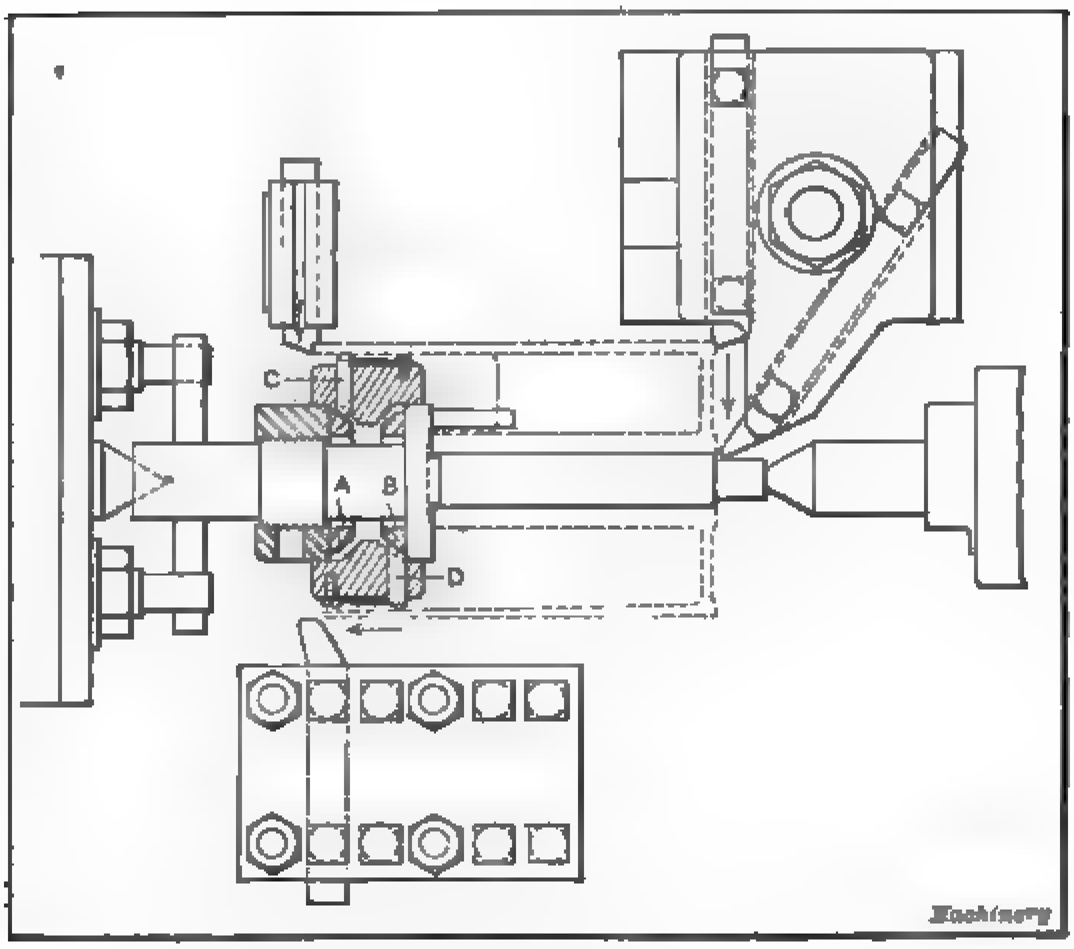

Fig. 20. Method of supporting Pulley from Inside while turning

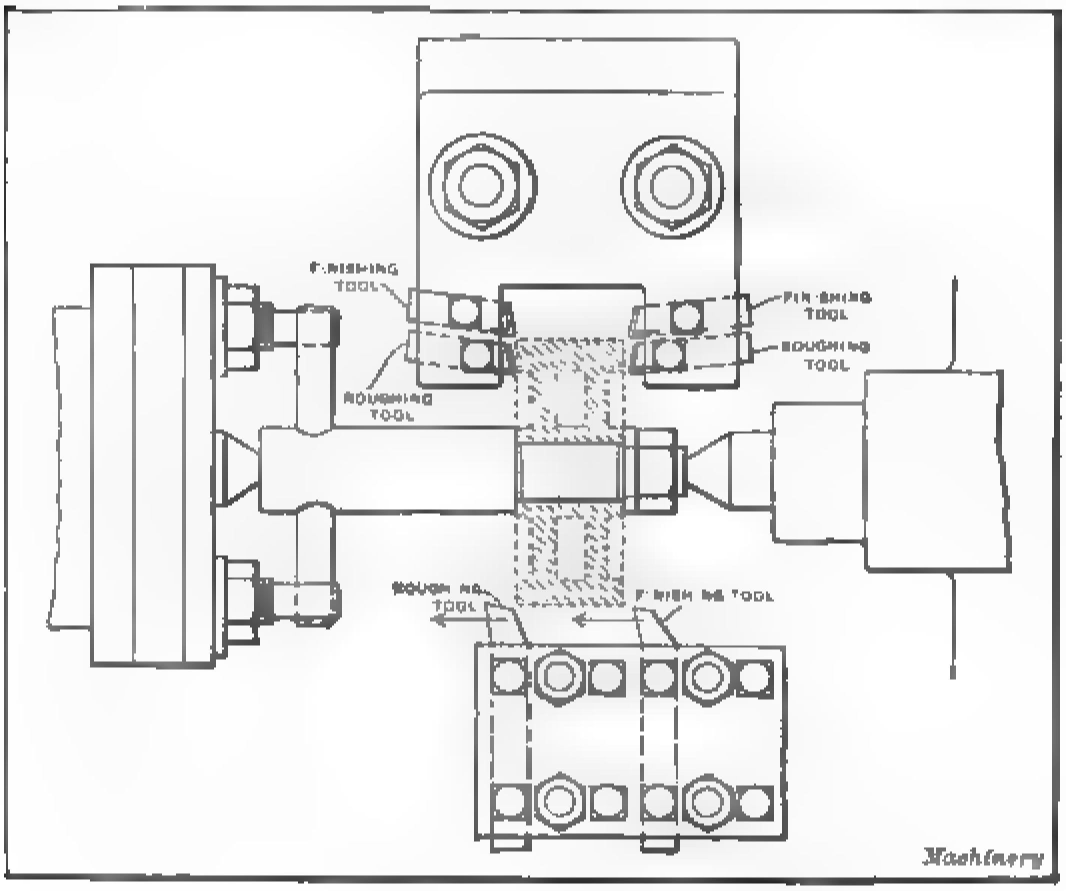

Fig. 21. Example of Arbor designed to hold Two Pieces of Work at One Time

position, the one to the left being located against a shoulder on the arbor. In order to use this arrangement for location, it is necessary

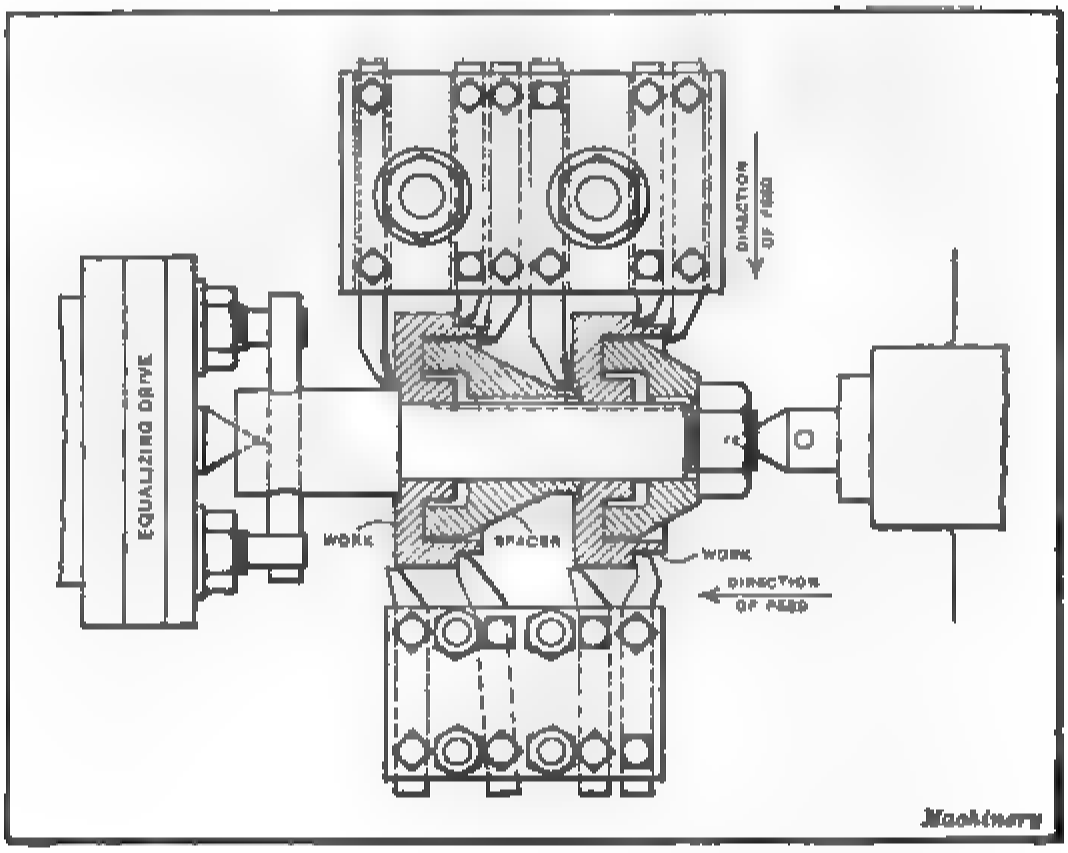

Fig. 22. Example of Two Pieces clamped on Arbor, illustrating Use of Spacer

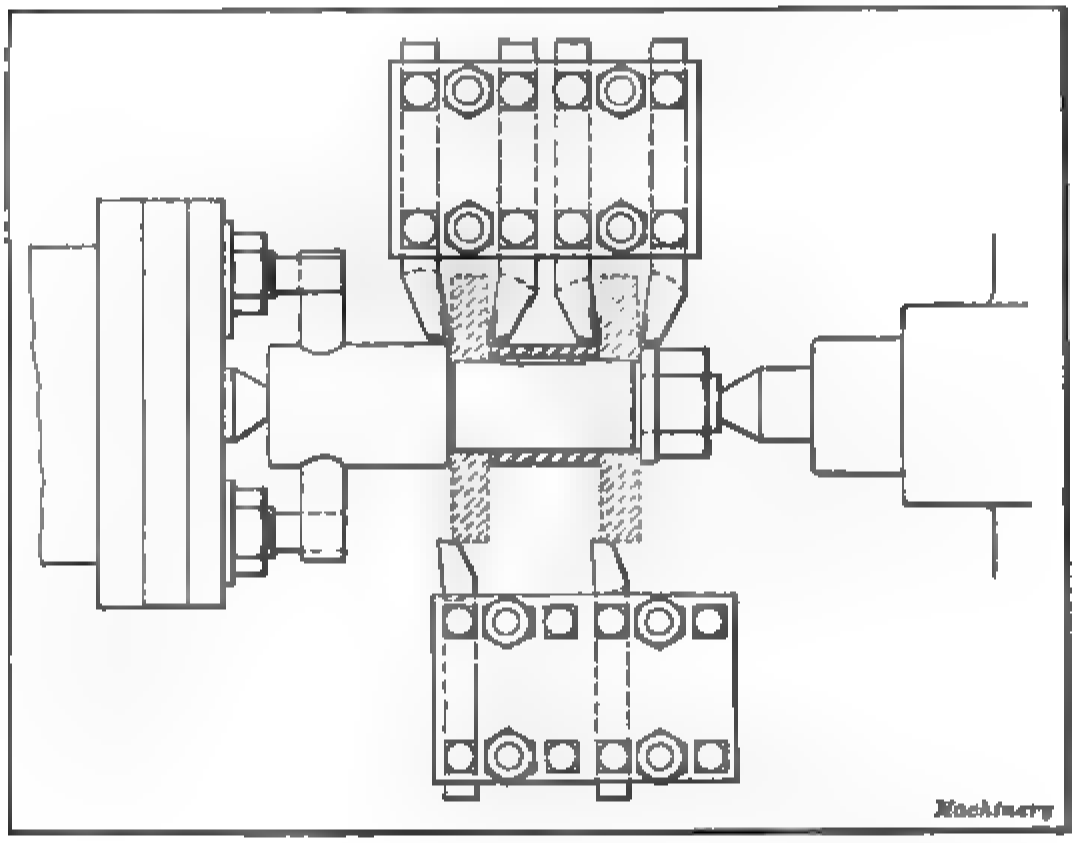

Fig. 23. A Simple Case of Two Pieces of Work held on an Arbor

for the work to have shoulders finished on two sides and also that the finishing be done accurately enough so that it can be used for locating

the two pieces. In this case both the clamping collar and the spacer are keyed to the arbor to make the drive more positive.

In Fig. 23 is shown another case of clamping two pieces using a spacer between them. It is evident that if the two sides of the hubs of the gear blanks had not previously been machined, this method could not be used as the gear blank to the right would not come in an accurate position to permit being machined by the tooling arrangement indicated.

In Fig. 24 is shown still another example of holding two pieces by means of a spacer. Here the roughing and finishing are done at the same time. The tools in the rear and front holders operate simultane-

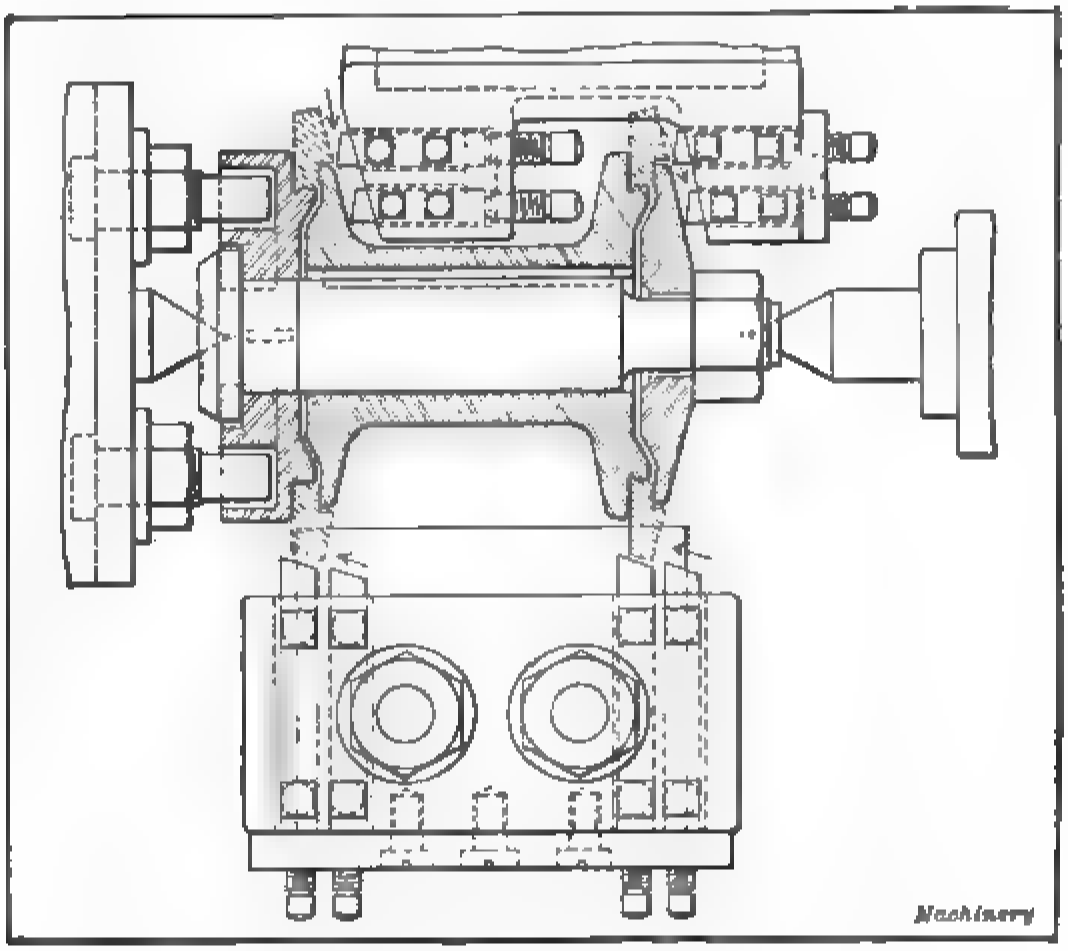

Fig. 24. Another Example of Use of Spacer between Two Pieces

ously, the taper attachment being used for the rear holder. A taper former is used on the former bar for the front tool-holder. Fig. 25 shows an especially interesting arrangement for holding two pieces and for supporting the thin walls of the bushings while machining. In this case the ends and the inside of the bushing are rough. The only difficulty that was met with was to machine them without distorting them on account of the thinness of the metal. The bushings are both centered and supported by the rough inside surface. For this purpose bushings *B* are provided on the arbor. These bushings hold plugs *C* which are prevented from falling out of their seats by springs when the pieces to be machined are to be rem
The arbor itself is provided with three flat spots
in the sectional view at the top. These act as

arbor is turned and force the plugs outward, thereby centering and supporting the work on the inside. This arbor shows a different method than those shown in the previous examples for holding two pieces at once. Here the middle portion of the arbor is solid and

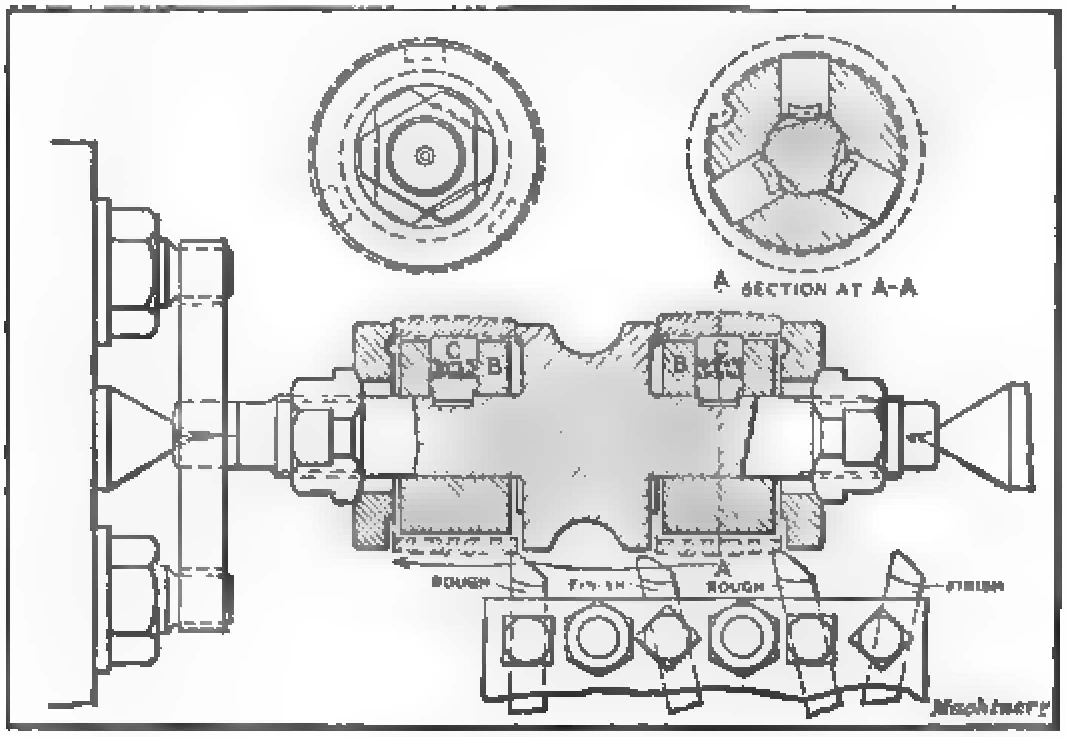

Fig. 26. Arbor for holding Two Pieces of Work which must be supported from the Inside

provided with three bearing points on each side for the work. Then collars are provided at each end of the arbor with nuts for clamping the work. One disadvantage is present with this arbor. The dog at the driving end must be removed to take off the pieces nearest to the head. In practically all the other cases shown a driving pin driven into the arbor can be used, as the work is removed in the other direction.